TM 11-5124

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

WATTMETER AN/URM-98

DEPARTMENT OF THE ARMY • NOVEMBER 1956

WARNING

DANGEROUS VOLTAGES EXIST IN THIS EQUIPMENT

Be careful when working on the 250-volt plate and power supply circuits, or on the 115- or 230-volt ac line connections.

TECHNICAL MANUAL
No. 11-5124

DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *20 November 1956*

WATTMETER AN/URM-98

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Figure 1. Wattmeter AN/URM–98.

CHAPTER 1
INTRODUCTION

Section I. GENERAL

1. Scope

a. This manual contains instructions for the installation, operation, maintenance, and repair of Wattmeter AN/URM–98 (fig. 1).

b. Forward comments on this publication direct to Commanding Officer, The Signal Corps Publications Agency, Fort Monmouth, N. J.

2. Forms and Records

a. Unsatisfactory Equipment Reports. Fill out and forward DA Form 468 (Unsatisfactory Equipment Report) to Commanding Officer, Signal Equipment Support Agency, Fort Monmouth, N. J. as prescribed in AR 700–38.

b. Damaged or Improper Shipment. Fill out and forward DD Form 6, Report of Damaged or Improper Shipment, as prescribed in AR 700–58 (Army); Navy Shipping Guide, Article 1850–4 (Navy); and AFR 71–4 (Air Force).

c. Preventive Maintenance Forms.

(1) DA Form 11–238 (Operator First Echelon Maintenance Check List for Signal Corps Equipment (Radio Communication, Direction Finding, Carrier, Radar)) will be prepared in accordance with instructions on the back of the form (fig. 9).

(2) DA Form 11–239 (Second and Third Echelon Maintenance Check List for Signal Corps Equipment (Radio Communication, Direction Finding, Carrier, Radar)) will be prepared in accordance with instructions on the back of the form (fig. 10).

Section II. DESCRIPTION AND DATA

3. Purpose and Use

a. Wattmeter AN/URM–98 is a portable test set that consists of Summation Bridge TS–779/U, Waveguide Probe MX–2144/U, and Cord CG–409/U. It is used to measure radio-frequency (RF) power either in milliwatts (mw) from 0 to 10 mw or in decibels referred to 1 milliwatt (dbm) from −20 to +10 dbm. It may be used at any frequency range for which a waveguide probe exists, and it measures either continuous or pulsed power with thermistor or barretter type waveguide probes.

b. Summation Bridge TS–779/U has a zero set feature and a closely regulated power supply. The performance stability permits measurements of low power levels under wide temperature variations.

c. Waveguide Probe MX–2144/U is a thermistor type bolometer mount which operates in the frequency range from 10 megacycles to 10 kilomegacycles. It provides the temperature sensitive element between the power source to be measured and the summation bridge. It does not require adjustment over the frequency range covered. Readings obtained from this waveguide probe are average power readings.

d. Figure 2 is a block diagram of Wattmeter AN/URM–98 in use. RF power from the equipment under test is fed through a test cable (not furnished with the wattmeter) to the Waveguide Probe MX–2144/U. The RF power reduces the thermistor resistance, thus unbalancing the bridge and causing a meter reading proportional to the RF power.

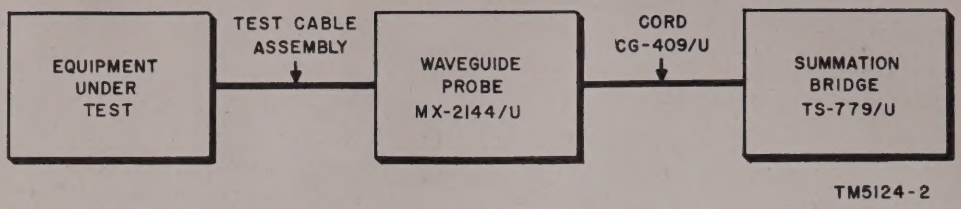


Figure 2. Wattmeter AN/URM–98, block diagram.

4. Technical Characteristics

a. Summation Bridge TS–779/U.

Frequency range	Depends on the associated waveguide probe used. May be used with waveguide probes which have either 100 or 200 ohms operating resistance and either positive or negative temperature coefficients.
Power range	Full scale readings of .1, .3, 1, 3 and 10 mw. Also calibrated in dbm to give continuous reading from −20 dbm to +10 dbm (0 dbm= 1 mw). All readings are for average power.
Dc bias current	Continuously adjustable and independent of waveguide probe resistance and power level range.
Accuracy	Within 5% of full scale value.
Power requirements	105 to 125 or 210 to 250 volts; 50/1000 cps.
Number of tubes	10.
Weight	20 lb.

b. Waveguide Probe MX–2144/U.

Frequency range	10 megacycles to 10 kilomegacycles.
Power range	0.01 to 10 mw when used with Summation Bridge TS–779/U.
Bolometer element	Thermistor type, negative temperature coefficient, 200 ohms resistance.
Standing wave ratio	Less than 1.5 to 1 full frequency range. (Less than 1.3 to 1 from 50 megacycles to 5 kilomegacycles.)

5. Common Names of Components

A list of nomenclature assignments for Wattmeter AN/URM–98 is given below. A common name is indicated after each item.

Nomenclature	Common name
Wattmeter AN/URM–98	Wattmeter.
Summation Bridge TS–779/U.	Summation bridge.
Waveguide Probe MX–2144/U.	Waveguide probe or bolometer.
Cord CG–409/U	Interconnect cable assembly.

6. Components

(fig 1)

Component	Reqd No.	Length (in.)	Width/or dia. (in.)	Height (in.)	Weight (lb)
Summation Bridge TS–779/U.	1	12¼	7⅜	11½	20
Waveguide Probe MX–2144/U.	1	3 3/16	1	------	¼
Cord CG–409/U	1	51	15	------	------
Set of Running Spares (par. 8).	1	------	------	------	------
TM 11–5124	2	10¼	7⅞	------	1

7. Description of Components

(fig. 1)

a. Summation Bridge TS–779/U. The summation bridge consists of a panel-chassis assembly contained in a steel housing. The housing is equipped with a leather carrying handle, four protective feet, and ventilating louvers on both sides, top, rear, and bottom. The support on the bottom of the housing holds the equipment at an angle for ease of operation. When not in use, the support may be folded up against the bottom of the housing. All operating controls and the input connector are located on the front panel. The power cord is attached to the chassis and extends through a hole in the back of the chassis. The power cord plug is polarized with two flat contacts and one round contact. (Refer to the note in par. 14.) A meter is mounted on the front panel and is calibrated in milliwatts and dbm.

b. Waveguide Probe MX–2144/U. The waveguide probe is a thermistor-type, temperature-sensitive device. It has a phenolic body with a male type N connector on one end and a Receptacle UG–1094/U on the other end. It contains two 100-ohm thermistors.

c. Cord CG–409/U. The interconnect cable assembly is a single-conductor shielded Cable RG–58/U with a Connector Plug UG–88/U on each end. It is 4-feet, 3-inches long and is used to connect the waveguide assembly to the summation bridge.

8. Running Spares

Following is a list of running spares for Wattmeter AN/URM–98. These items are packaged in a separate carton in the equipment packing case.

1 tube, 6AV6
1 tube, 6AV5GT
2 tubes, 6CB6
1 tube, 5Y3
1 tube, 12AX7
1 tube, 5651
6 fuses, 1 ampere, type 3AG
1 panel lamp, 6.3 volts, .15 ampere

CHAPTER 2
INSTALLATION

Section I. SERVICE UPON RECEIPT OF WATTMETER AN/URM–98

9. Packaging Data
(fig. 3)

When packaged for export shipment, the components of Wattmeter AN/URM–98 are packed as follows: The summation bridge is placed in an inner corrugated carton and blocked in place with corrugated pads. A sheet of wadding is placed on top of the summation bridge. Waveguide Probe MX–2144/U and Cord CG–409/U are placed in a sealed plastic bag and stored in the carton with the running spares. This carton is placed on top of the sheet of wadding in the carton with the summation bridge and blocked in place with corrugated pads. The inner corrugated carton is sealed in a moisture-vaporproof barrier. The inner corrugated carton is then placed in an outer corrugated carton. The manuals are contained in a sealed waterproof bag and placed in the top of the outer carton. The outer carton is then inclosed in a waterproof barrier and placed in a wooden crate. The wooden crate cover is nailed on and secured with two metal straps that wrap completely around the crate. A typical component packed for export shipment is shown in figure 3. The wattmeter will be packed in a single crate. The packing crate dimensions are—16¼ inches high, 26¼ inches wide, 11¾ inches deep with a volume of 2.92 cubic feet and a weight of 55 pounds.

Caution: Be careful when uncrating, unpacking, and handling the equipment; it is easily damaged.

10. Unpacking and Checking

a. Step-by-step Instructions for Uncrating and Unpacking Export Shipments (fig. 3).

(1) Place the packing case on a table or workbench.

(2) Cut and fold back the metal straps.

(3) Remove the nails with a nail puller. Remove the top and sides of the packing case. Do not attempt to pry off the sides and top; the equipment may become damaged.

(4) Carefully cut and remove the waterproof liner.

(5) Open the outer corrugated carton and remove the inner corrugated carton.

(6) Carefully cut and remove the moisture-vaporproof barrier.

(7) Remove the small corrugated carton that contains the cable assembly, waveguide probe, and running spares.

(8) Remove the corrugated cardboard and felt packing and lift the summation bridge out of the carton.

b. Checking New Equipment. Thoroughly check the equipment for damaged or missing parts. To be sure that the shipment is complete, compare the items on the packing list with the actual equipment received. If the equipment is incomplete or has been damaged in shipment, refer to paragraph 2*b*.

c. Cleaning New Equipment. After the equipment has been thoroughly checked, clean all items with a soft cloth.

d. Unpacking Domestic Packing Cases. The wattmeter may be received in domestic packing cases. The instructions given in *b* above apply also to unpacking domestic shipments. Cut the metal bands. Open the cartons that protect the equipment; or, if heavy wrapping paper has been used, remove it carefully and take out the components. Check the contents of the packing case against the master packing slip.

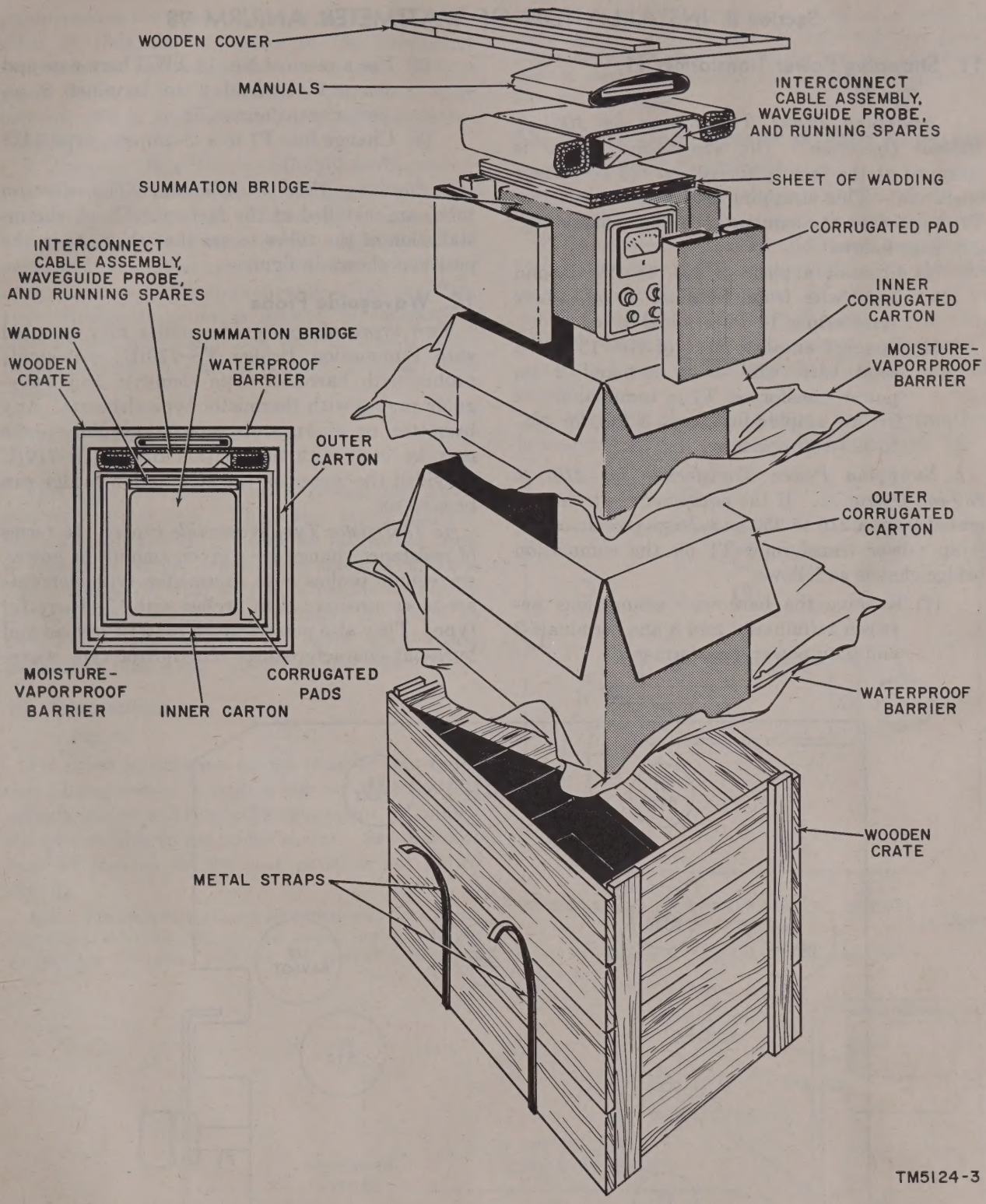


Figure 3. Wattmeter AN/URM–98, packaging diagram.

Section II. INSTALLATION OF WATTMETER AN/URM-98

11. Strapping Power Transformer T1

(fig. 26)

a. Strapping Power Transformer for 105- to 125-volt Operation. The summation bridge is strapped at the factory for 105 to 125 ac voltage operation. This strapping of power transformer T1, located on the summation bridge chassis (fig. 20), is as follows:

(1) Connect a piece of No. 18 AWG solid bare wire from terminal 1 on power transformer T1 to terminal 8.

(2) Connect another piece of No. 18 AWG solid bare wire from terminal 2 on power transformer T1 to terminal 9.

(3) Use a 1-ampere fuse, type 3 AG, for 105- to 125-volt operation (fig. 5).

b. Strapping Power Transformer for 210- to 250-volt Operation. If the equipment is to be operated from a 210 to 250 ac voltage power source, strap power transformer T1 on the summation bridge chassis as follows:

(1) Remove the bare wire connections between terminals 1 and 8 and terminals 2 and 9 on power transformer T1.

(2) Use a piece of No. 18 AWG bare wire and connect terminal 2 to terminal 8 on power transformer T1.

(3) Change fuse F1 to a .5-ampere, type 3AG fuse (fig. 5).

c. Checking Tube Installation. The electron tubes are installed at the factory. Check the installation of the tubes to see that they are in the positions shown in figure 4.

12. Waveguide Probe

Two types of waveguide probes may be used with Summation Bridge TS–779/U: waveguide probes with barretter type elements and waveguide probes with thermistor type elements. Any barretter or thermistor type waveguide probe may be used with Summation Bridge TS–779/U provided the meter on the summation bridge can be zero set.

a. Thermistor Type Waveguide Probes. In terms of resistance change for a given amount of power, waveguide probes with thermistor type elements are more sensitive than probes with the barretter type. They also possess much better overload and burn-out characteristics. Thermistor type wave-

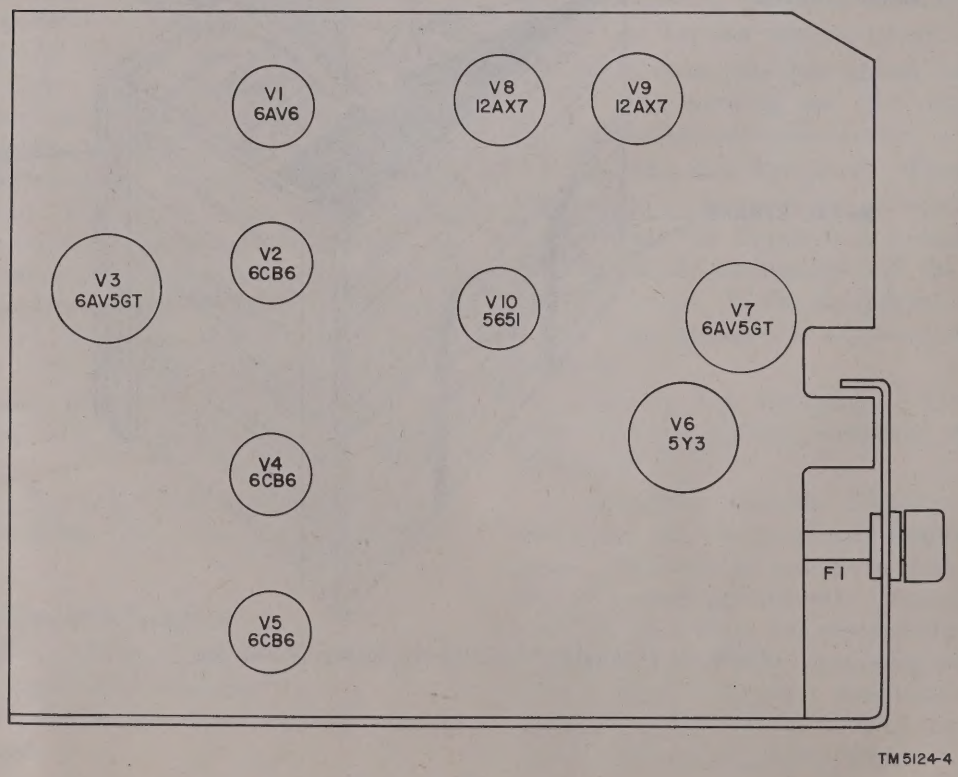


Figure 4. Tube locations.

guide probes have a negative temperature coefficient in that the resistance of the thermistor decreases as its temperature increases. Waveguide Probe MX–2144/U has a thermistor type element and is supplied as a part of Wattmeter AN/URM–98.

b. Barretter Type Waveguide Probes. Barretter type waveguide probes have a positive temperature coefficient in that their resistance increases with temperature. They are usually constructed of encapsulated platinum wire or resistive coatings on glass or mica. The power range of the barretter type waveguide probe is limited in contrast to that of the thermistor but its response is more rapid because it has a shorter thermal time constant.

13. Test Cable Assembly

(fig. 6)

For some measurements, a special test cable assembly is required. This cable is *not* supplied with the equipment. It may be fabricated from a length of single conductor, shielded Coaxial Cable RG–58/U with a type N female connector on each end. This cable should be short as possible. Long lengths of cable may cause impedance mismatch. (Refer to par. 19*e*.)

14. Connections

(fig. 6)

Place the summation bridge close to the equipment being tested in such a manner that the test cable assemby will reach the equipment. Connect the power cable to the power source. See that line fuse Fl located on the rear panel is not blown (fig. 5).

Note. The connector plug on the power cord has a round grounding terminal. If the ac power outlet will not accomodate this plug, pull out the grounding terminal with a pair of pliers. Further connections are given in paragraphs 19 and 20 with the operating procedures. These connections are given with the operating procedures because certain precautions and sequence of operation have to be followed.

15. Service Upon Receipt of Used or Reconditioned Equipment

a. Follow the instructions in paragraph 10 for uncrating, unpacking, and checking the equipment.

b. Check the used or reconditioned equipment for tags or other indications pertaining to changes in wiring of the equipment. If any changes in wiring have been made, note the changes in this manual, preferably on the schematic diagram.

c. Check the operating controls for ease of rotation.

d. Perform the installation and connection procedures given in paragraphs 11 through 14.

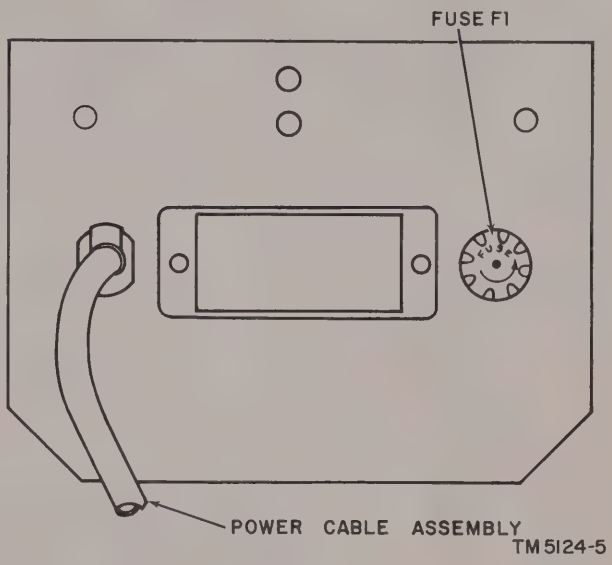


Figure 5. Rear panel, fuse location.

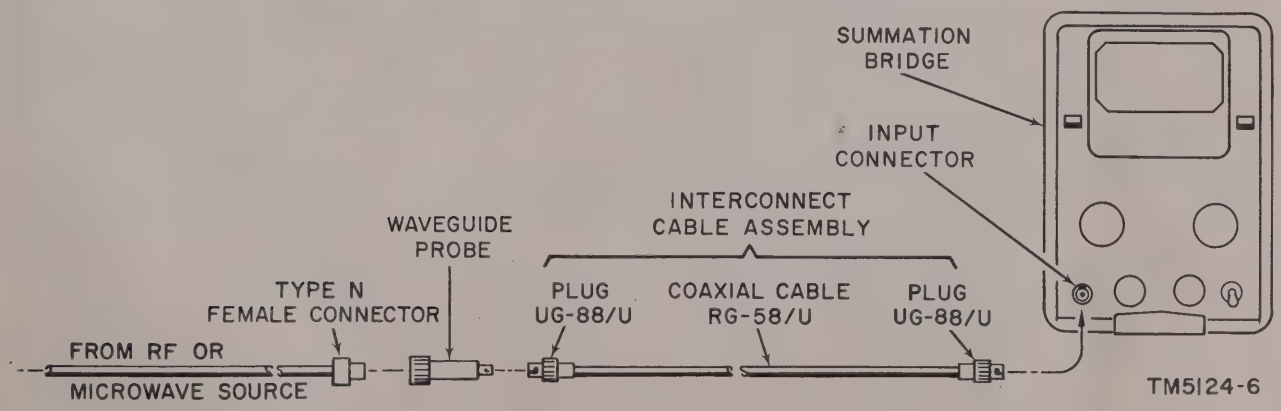


Figure 6. Connections for making power measurements.

CHAPTER 3

OPERATION

Section I. CONTROLS AND INSTRUMENTS

16. General

Haphazard operation or improper setting of the BIAS CURRENT switch, POWER RANGE switch, COEF. switch, and RES. switch can cause damage to Wattmeter AN/URM–98. It is therefore important to know the function of every control and the meter on the equipment. The actual operating instructions are contained in paragraphs 18 through 20.

17. Controls and Their Uses

The following chart lists the controls and instruments of the summation bridge (fig. 7) and indicates what they do:

Control	Function
ON switch	Turns on equipment.
BIAS CURRENT switch.	Rotary switch for selecting dc bias current range required by waveguide probe for zero setting the instrument prior to actual exposure to a source of RF or microwave power. In addition to an OFF position, there are 10 ranges as follows: 0–6 ma, 6 to 10 ma in three uncalibrated steps, and 10 to 16 ma in six uncalibrated steps.
ZERO SET COARSE control.	Provides a coarse adjustment of the dc bias current when referencing the meter at zero scale reading prior to exposure of the external waveguide probe to a source of RF or microwave power.
FINE control	Provides a fine adjustment of the dc bias current when referencing the meter at zero scale reading prior to exposure of the external waveguide probe to a source of RF or microwave power.
POWER RANGE switch.	Rotary switch for selecting the desired power level range of measurements. Calibrated in milliwatts and dbm as follows: .10 mw (−10 dbm), .3 mw (−5 dbm), 1 mw (0 dbm), 3 mw (+5 dbm), and 10 mw (+10 dbm).
COEF. POS.-NEG. switch.	Two-position switch for selecting bridge circuit connections corresponding to the temperature coefficient of the external waveguide probe. (Barretter type requires a positive coefficient setting and thermistor type requires a negative coefficient setting.)
RES. 200–100 switch	Two-position switch for selecting bridge arm resistances required to accommodate either a 100- or 200-ohm waveguide operating resistance. (Waveguide Probe MX–2144/U requires a setting of 200 ohms.)
Input connector J1	Jack used to connect cable from waveguide probe into bridge circuit.
Power on light	Lights when primary power is on.

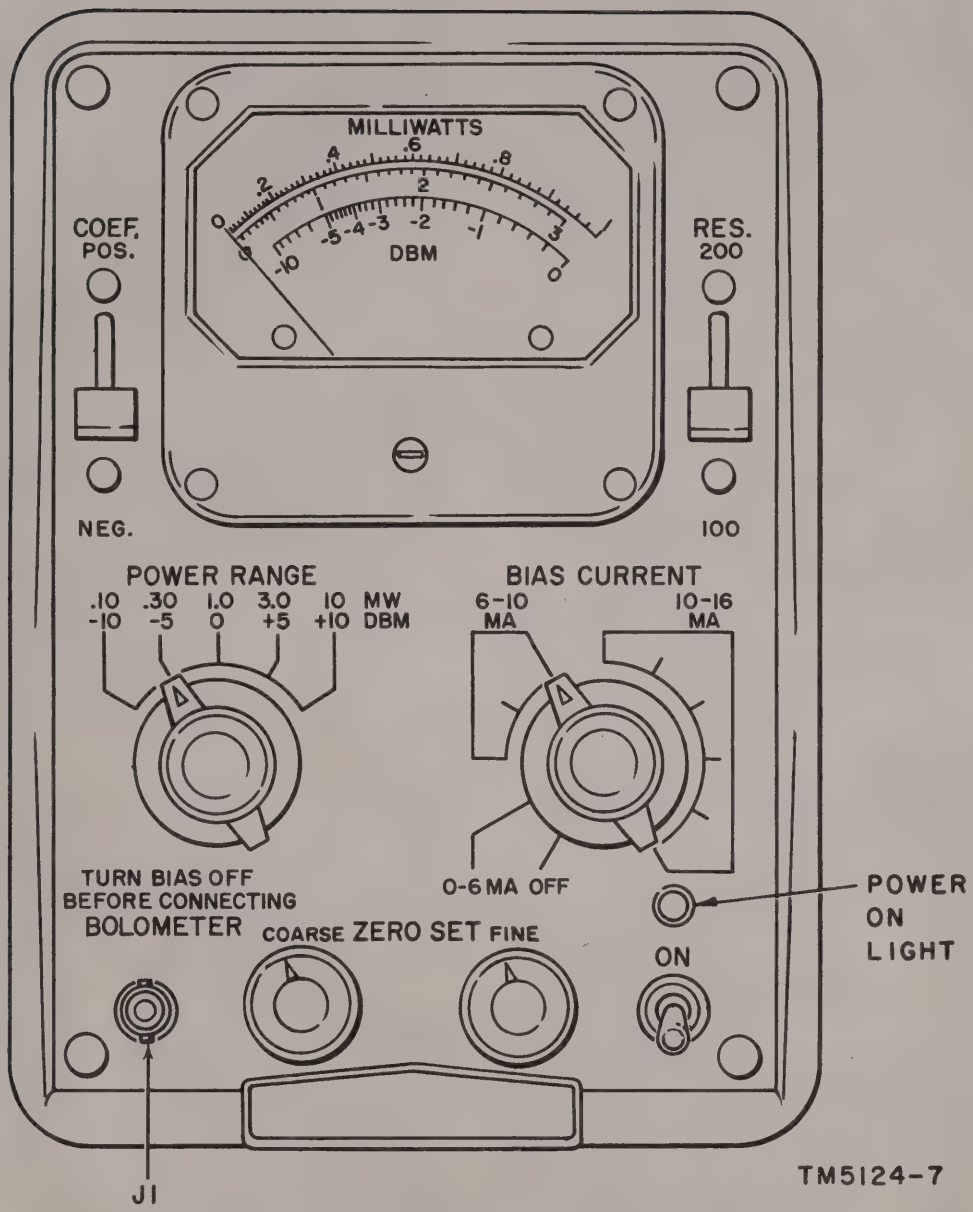


Figure 7. Summation Bridge TS-779/U, controls and instruments.

18. Starting Procedure

Perform the starting procedure given below before using the operating procedure described in paragraph 19.

Caution: Do not connect the power cord to the ac outlet until the strapping options for power transformer T1 (par. 11) have been checked. Do not allow the power cord to drape across high-voltage or RF circuits. Severe burns or shock and damage to the equipment may result.

a. Preliminary (fig. 17). Set the front panel controls as follows:

Control	Position
ON switch	To OFF position.
BIAS CURRENT switch.	To OFF position.
COEF. POS.-NEG. switch.	To appropriate setting for type of external waveguide probe being used. (For Waveguide Probe MX–2144/U, set switch in NEG. position.)
RES. 200–100 switch	To appropriate setting for type of external waveguide probe being used. (For Waveguide Probe MX–2144/U, set switch in 200 position.)

Caution: The BIAS CURRENT switch must always be set in the OFF position before connecting the external waveguide probe.

b. Starting.

(1) Throw the line ON switch to the ON position. The pilot lamp should glow. Allow the equipment to warm up for at least 5 minutes. Check to see that the pointer on the meter rests off scale at the high end.

(2) Set the POWER RANGE switch for the range of power under measurement, if known. If amount of power source is unknown, set the POWER RANGE switch to its highest range (10 MW).

(3) Check to see that the BIAS CURRENT is in the OFF position and connect the waveguide probe to the input connector (J1); use the interconnect cable assembly. *Do not* connect the waveguide probe to the equipment under test.

(4) Place the ZERO SET controls to their full clockwise positions.

(5) Place the BIAS CURRENT switch in the 0–6 MA position. If the pointer on the meter remains off scale at the high end or moves down to a position on scale, follow the procedure in (6) below. If the pointer on the meter reverses its position and rests off scale at the low end, follow the procedure in (7) below.

(6) If the pointer on the meter remains off scale at the high end or moves down to a position on scale ((5) above), zero set the meter with the ZERO SET controls. Rotate the COARSE control counterclockwise until the pointer on the meter is as close as possible to zero. Rotate the FINE control counterclockwise until the pointer on the meter rests on zero.

(7) If the pointer on the meter reverses its position and rests off scale at the low end ((5) above), increase the BIAS CURRENT switch one step at a time until the pointer on the meter moves on scale or off scale at the high end. Zero set the meter with the ZERO SET controls as described in (6) above.

Note. If, during the starting procedure, an abnormal result is obtained, refer to the equipment performance checklist (par. 32).

19. Operating Procedure

The POWER RANGE switch may be set to increase or decrease the sensitivity of the meter. Each time the position is changed, the meter must be zero set as described in paragraph 18. Power readings may be made in milliwatts or dbm.

a. Taking Dbm Readings. Each setting of the POWER RANGE switch corresponds to a full-scale reading on the meter. When the switch is set to the 0 DBM position, power readings are read directly from the meter. Switch settings −5 and −10 DBM increase the sensitivity of the wattmeter by −5 and −10 dbm. When the switch is in one of these positions, the number of the position (−5 or −10) must be added to the indicated meter reading. For example, if the switch is set at −5 DBM, a meter indication of −3 would be added to −5 dbm so that the actual indicated power would be −8 dbm. The +5 and +10 DBM positions of the switch decrease the sensitivity of the meter by +5 and +10 dbm respectively. When the switch is in one of these

positions, the number of the position (+5 or +10) must be algebraically added to the meter indication. For example, if the switch is in +10 DBM position, a meter indication of −3 would be added to +10 to give an indicated power reading of +7 dbm.

b. Taking Milliwatt Readings. When taking power readings in milliwatts, the 1.0 MW position of the POWER RANGE switch corresponds to a full-scale reading of 1.0 mw so that power readings are read directly from the meter. The .10 and .30 MW positions of the switch change the full scale readings to .10- and .30-mw respectively. When the switch is in one of these positions, the actual power is the indicated meter reading times the equivalent percentage of the number of the switch position (.10 or .30). For example, if the switch is set at .10 MW, a meter indication of .3 mw would be multiplied by .10 to give an actual power reading of .03 mw. Likewise, if the switch is set at .30 MW, a meter indication of .3 mw would be multiplied by .30 to give an actual power reading of .09 mw. The 0 to 3 middle scale can be used only with milliwatts.

c. Operation. When the procedures described in *a* and *b* above have been completed, operate the watt meter as described below. *For best results, make measurements as soon as possible after the meter has been zero set.* Readings are for *average power.*

Note. The power source to be measured must have a female type N connector on the cable used for connecting the waveguide probe.

(1) Connect the waveguide probe to the RF source to be measured. The waveguide assembly may be connected to the RF source through the test cable assembly (par. 13).

(2) If the range of the power to be measured is not known, set the POWER RANGE switch to the 10 MW position.

(3) If there is only a small clockwise deflection of the meter, increase the sensitivity of the meter by rotating the POWER RANGE switch to a lower range. Each time the POWER RANGE switch is changed, the meter must be zero set as described in paragraph 8. Refer to *a* and *b* above for calculating the readings.

Note. When making measurements in the 0.1 mw range, allow 1 hour for the temperature to stabilize after turning on the instrument. Zero set the meter just prior to making the measurement.

(4) If the meter pointer pins against the right stop, reduce the meter sensitivity by rotating the POWER RANGE switch to a higher range. Zero set the meter as described in paragraph 18. Calculate the readings as instructed in *a* and *b* above.

d. Temperature. The waveguide probe is a temperature-sensitive device, and inconsistent results will be obtained when a cold waveguide assembly is attached to a warm object. Always allow the temperature of the waveguide probe to reach that of the equipment under measurement.

e. Error in Power Readings. For most applications, the summation bridge will give useful readings. When extremely accurate readings are required, error in power readings may be determined if the voltage standing wave ratio of the RF source and the waveguide probe are known. Error in power readings may be caused by impedance mismatches between the RF source and the waveguide probe. If there is impedance mismatch, the power loss lies between two limits as shown in the chart in figure 8. To determine these limits, locate the point on the chart at which the voltage standing wave ratio of the RF source and that of the waveguide probe intersect. At this point, find the nearest cross section of the solid and dotted diagonal lines. The number on the solid line represents the lowest possible power loss correction. The number on the dotted diagonal line represents the highest possible power loss correction. Both power loss corrections are given in db. Refer to the decibel table below to find the power ratios corresponding to these two db values. For the highest possible true power, multiply the meter reading by the highest of the two power ratios. For the lowest possible true power, multiply the meter reading by the lowest of these power ratios. All power readings are computed in milliwatts. After the highest and lowest true powers have been computed, they can be converted to dbm simply by referring to the meter scale.

Power ratio	Decibels	Power ratio	Decibels
1.0233	.1	1.1749	.7
1.0471	.2	1.2023	.8
1.0715	.3	1.2303	.9
1.0965	.4	1.2589	1.0
1.1220	.5	1.3183	1.2
1.1482	.6	1.3804	1.4

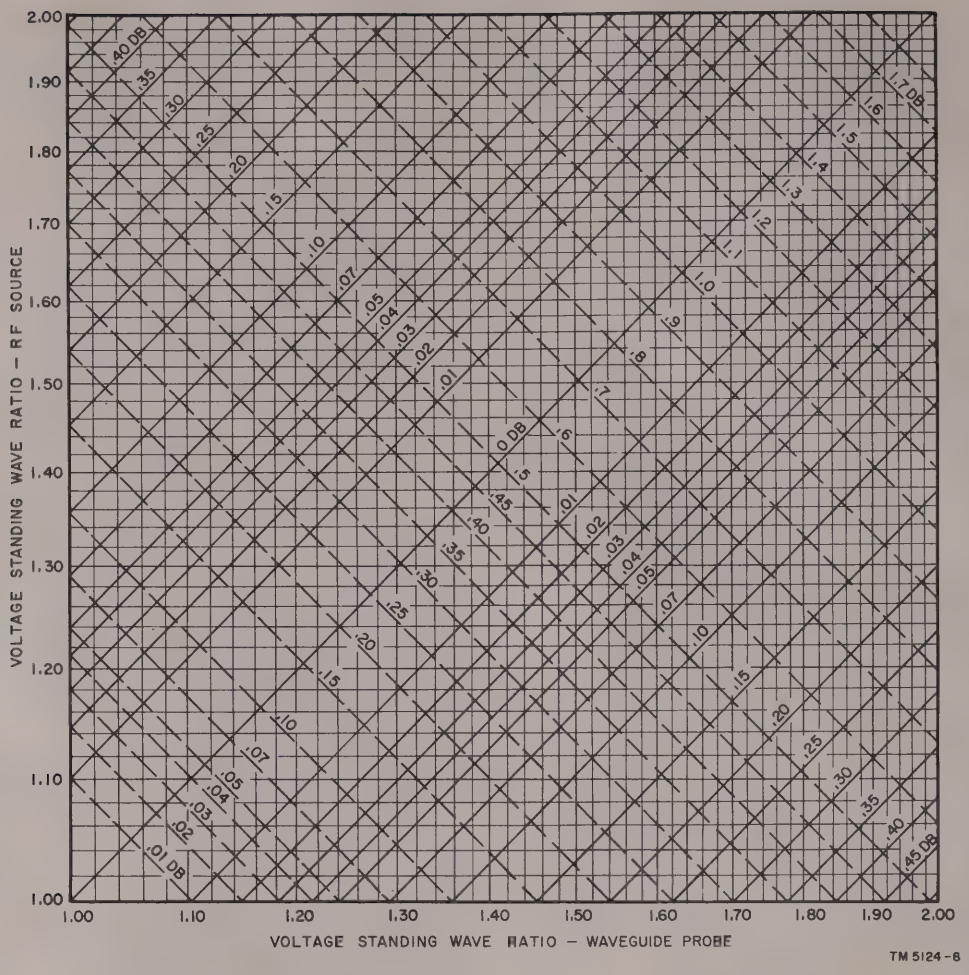


Figure 8. Waveguide Probe MX–2144/U line mismatch loss.

f. Normally the voltage standing wave ratio of the waveguide probe will fall between 1.3 to 1 and 1.5 to 1 as given in the technical characteristics (par. 4). Using one of these values, depending on the frequency of the source, and using the voltage standing wave ratio given for the equipment being measured, determine the minimum and maximum correction factors from the chart (fig. 8). The corrected power values obtained (*e* above) are as accurate as normally required. If more accurate readings are necessary, the voltage standing wave ratio of the source and the wave guide probe can be measured with Coaxial Slotted Line IM–92/U (TM 11–5109).

20. Stopping Procedure

a. Turn the BIAS CURRENT switch to the OFF position.

b. Turn the line ON switch to the OFF position.

c. Disconnect the special test cable assembly from the waveguide probe and the interconnect cable assembly from the waveguide probe and the input jack on the front panel.

d. Disconnect the line cord from the power outlet.

e. Store the summation bridge, waveguide probe and the interconnect cable assembly in the corrugated packing case.

CHAPTER 4
ORGANIZATIONAL MAINTENANCE

Section I. TOOLS AND EQUIPMENT

21. General

a. A number of tools, materials, or tool equipment kits are either furnished with the equipment or supplied to the organization for use with the equipment.

b. The actual allowable organizational maintenance that can be performed on Wattmeter AN/URM–98 depends on the tools and other test equipment issued.

22. Tools and Materials

Tools and materials used, but not supplied, with Wattmeter AN/URM–98 are listed in *a* and *b* below.

a. Tools. Tool Equipment TE–113 contains all tools that are necessary for organizational maintenance of this equipment.

b. Materials.

Cheesecloth, bleached, lint-free.

Cleaning Compound (Federal Stock No. 7930–395–9542).

Sandpaper, flint No. 000.

Section II. PREVENTIVE MAINTENANCE SERVICES

23. Definition of Preventive Maintenance

Preventive maintenance is work performed on equipment (usually when the equipment is not in use) to keep it in good working order so that breakdowns and needless interruptions in service will be kept to a minimum. Preventive maintenance differs from troubleshooting and repair since its object is to prevent certain troubles from occurring.

24. General Preventive Maintenance Techniques

a. Use No. 000 sandpaper to remove corrosion.

b. Use clean, dry, lint-free cloth or a dry brush for cleaning. If necessary, moisten the cloth or brush with Cleaning Compound; after cleaning, wipe the parts dry with a cloth.

Warning: Prolonged breathing of Cleaning Compound fumes is dangerous. Be sure that adequate ventilation is provided. Cleaning Compound is flammable; do not use near a flame.

25. Use of Preventive Maintenance Forms (Figs. 9 and 10)

a. DA Form 11–238 is a preventive maintenance checklist to be used by the operator.

b. DA Form 11–239 is a preventive maintenance checklist to be used by second echelon repairman as directed by his commander.

c. Items not applicable to Wattmeter AN/URM–98 are lined out on figures 9 and 10. References in the ITEM column refer to paragraphs in this manual which contain additional maintenance information pertinent to the particular item. Instructions for the use of each form appear on the reverse side of the form.

26. First Echelon Preventive Maintenance

Caution: Tighten screws, bolts and nuts, carefully. Fittings tightened beyond the pressure for which they are designed will be damaged or broken.

The instructions in this paragraph form a suggested schedule of preventive maintenance procedures for the operator of Wattmeter AN/URM–98.

a. Daily.

(1) Check for completeness and general condition of the summation bridge. The components of the summation bridge and accessories are listed in paragraph 6.

OPERATOR FIRST ECHELON MAINTENANCE CHECK LIST FOR SIGNAL CORPS EQUIPMENT

RADIO COMMUNICATION, DIRECTION FINDING, CARRIER, RADAR

INSTRUCTIONS: See other side

EQUIPMENT NOMENCLATURE	EQUIPMENT SERIAL NO.
WATTMETER AN/URM-98	000

LEGEND FOR MARKING CONDITIONS: ✓ Satisfactory; X Adjustment, repair or replacement required; (X) Defect corrected.
NOTE: Strike out items not applicable.

DAILY

NO.	ITEM	CONDITION S	M	T	W	T	F	S
1	COMPLETENESS AND GENERAL CONDITION OF EQUIPMENT *(receiver, ~~transmitter, carrying cases, wire and~~ cable, microphones, tubes, spare parts, technical manuals and accessories).* PAR 26a (1)	✓	✓	✓	✓	✓	✓	✓
2	~~LOCATION AND INSTALLATION SUITABLE FOR NORMAL OPERATION.~~							
3	~~CLEAN DIRT AND MOISTURE FROM ANTENNA, MICROPHONE, HEADSETS, CHESTSETS, KEYS,~~ JACKS, PLUGS, ~~TELEPHONES, CARRYING BAGS, COMPONENT PANELS.~~							
4	~~INSPECT SEATING OF READILY ACCESSIBLE "PLUCK OUT" ITEMS: TUBES, LAMPS, CRYSTALS, FUSES, CONNECTORS, VIBRATORS, PLUG-IN COILS AND RESISTORS.~~							
5	~~INSPECT CONTROLS FOR BINDING, SCRAPING, EXCESSIVE LOOSENESS, WORN OR CHIPPED GEARS, MISALIGNMENT, POSITIVE ACTION.~~							
6	CHECK FOR NORMAL OPERATION. PAR 26a (5)	✓	✓	✓	✓	✓	✓	✓

WEEKLY

NO.	ITEM	CONDITION	NO.	ITEM	CONDITION
7	CLEAN AND TIGHTEN EXTERIOR OF COMPONENTS AND CASES, ~~RACK MOUNTS, SHOCK MOUNTS, ANTENNA MOUNTS,~~ COAXIAL TRANSMISSION LINES, WAVE GUIDES, AND CABLE CONNECTIONS.	✓	13	~~INSPECT STORAGE BATTERIES FOR DIRT, LOOSE TERMINALS, ELECTROLYTE LEVEL AND SPECIFIC GRAVITY, AND DAMAGED CASES.~~	
8	INSPECT ~~CASES, MOUNTINGS, ANTENNAS, TOWERS, AND~~ EXPOSED METAL SURFACES, FOR RUST, CORROSION, AND MOISTURE. PAR 26b (2)	✓	14	~~CLEAN AIR FILTERS, BRASS NAME PLATES, DIAL AND METER WINDOWS, JEWEL ASSEMBLIES.~~	
9	INSPECT CORD, CABLE, ~~WIRE, AND SHOCK MOUNTS~~ FOR CUTS, BREAKS, ~~FRAYING, DETERIORATION,~~ KINKS, AND STRAIN. PAR 26b (3)	(X)	15	INSPECT METERS FOR DAMAGED GLASS AND CASES. PAR 26b (5)	✓
10	~~INSPECT ANTENNA FOR ECCENTRICITIES, CORROSION, LOOSE FIT, DAMAGED INSULATORS AND REFLECTORS.~~		16	~~INSPECT SHELTERS AND COVERS FOR ADEQUACY OF WEATHER PROOFING.~~	
11	~~INSPECT CANVAS ITEMS, LEATHER, AND CABLING FOR MILDEW, TEARS, AND FRAYING.~~		17	~~CHECK ANTENNA GUY WIRES FOR LOOSENESS AND PROPER TENSION.~~	
12	INSPECT FOR LOOSENESS OF ACCESSIBLE ITEMS: SWITCHES, KNOBS, JACKS, CONNECTORS, ~~ELECTRICAL TRANSFORMERS, POWER STATS, RELAYS, SELSYNS, MOTORS, BLOWERS, CAPACITORS, GENERATORS,~~ AND PILOT LIGHT ASSEMBLIES. PAR 26b (1),(4)	✓	18	~~CHECK TERMINAL BOX COVERS FOR CRACKS, LEAKS, DAMAGED GASKETS, DIRT AND GREASE.~~	

19 IF DEFICIENCIES NOTED ARE NOT CORRECTED DURING INSPECTION, INDICATE ACTION TAKEN FOR CORRECTION.

DA FORM 1 MAY 51 11-238 REPLACES DA AGO FORM 419, 1 DEC 50, WHICH IS OBSOLETE.

TM5124-9

Figure 9. DA Form 11–238.

SECOND AND THIRD ECHELON MAINTENANCE CHECK LIST FOR SIGNAL CORPS EQUIPMENT
RADIO COMMUNICATION, DIRECTION FINDING, CARRIER, RADAR

INSTRUCTIONS: See other side

EQUIPMENT NOMENCLATURE: WATTMETER AN/URM-98

EQUIPMENT SERIAL NO.: 000

LEGEND FOR MARKING CONDITIONS: ✓ Satisfactory; X Adjustment, repair or replacement required; ⓧ Defect corrected.
NOTE: Strike out items not applicable.

NO.	ITEM	CONDITION
1	COMPLETENESS AND GENERAL CONDITION OF EQUIPMENT (~~receiver, transmitter, carrying cases, wire and~~ cable, ~~microphones~~, tubes, spare parts, technical manuals and accessories).	✓
2	LOCATION AND INSTALLATION SUITABLE FOR NORMAL OPERATION.	✓
3	CLEAN DIRT AND MOISTURE FROM ~~ANTENNA, MICROPHONE, HEADSETS, CHESTSETS, KEYS,~~ JACKS, PLUGS, ~~TELEPHONES, CARRYING BAGS,~~ COMPONENT PANELS.	ⓧ
4	INSPECT SEATING OF READILY ACCESSIBLE "PLUCK-OUT" ITEMS: ~~TUBES, LAMPS, CRYSTALS,~~ FUSES, CONNECTORS, ~~VIBRATORS, PLUG-IN COILS AND RESISTORS.~~	✓
5	INSPECT CONTROLS FOR BINDING, SCRAPING, EXCESSIVE LOOSENESS, ~~WORN OR CHIPPED GEARS,~~ MISALIGNMENT, POSITIVE ACTION. PAR 27b	✓
6	CHECK FOR NORMAL OPERATION.	ⓧ
7	CLEAN AND TIGHTEN EXTERIOR OF COMPONENTS ~~AND CASES, RACK-MOUNTS, SHOCK MOUNTS, ANTENNA MOUNTS,~~ COAXIAL TRANSMISSION LINES, WAVE GUIDES, AND CABLE CONNECTIONS.	✓
8	INSPECT ~~CASES, MOUNTINGS, ANTENNAS, TOWERS, AND~~ EXPOSED METAL SURFACES, FOR RUST, CORROSION, AND MOISTURE.	✓
9	INSPECT CORD, CABLE, ~~WIRE, AND SHOCK MOUNTS~~ FOR CUTS, BREAKS, FRAYING, DETERIORATION, KINKS, AND STRAIN.	✓
10	~~INSPECT ANTENNA FOR ECCENTRICITIES, CORROSION, LOOSE FIT, DAMAGED INSULATORS AND REFLECTORS.~~	
11	~~INSPECT CANVAS ITEMS, LEATHER, AND CABLING FOR MILDEW, TEARS, AND FRAYING.~~	
12	INSPECT FOR LOOSENESS OF ACCESSIBLE ITEMS: SWITCHES, KNOBS, JACKS, CONNECTORS, ~~ELECTRICAL TRANSFORMERS, POWERSTATS, RELAYS, SELSYNS, MOTORS, BLOWERS, CAPACITORS, GENERATORS,~~ AND PILOT LIGHT ASSEMBLIES.	✓
13	~~INSPECT STORAGE BATTERIES FOR DIRT, LOOSE TERMINALS, ELECTROLYTE LEVEL AND SPECIFIC GRAVITY, AND DAMAGED CASES.~~	
14	~~CLEAN AIR FILTERS, BRASS NAME PLATES, DIAL AND METER WINDOWS, JEWEL ASSEMBLIES.~~	
15	INSPECT METERS FOR DAMAGED GLASS AND CASES.	✓
16	~~INSPECT SHELTERS AND COVERS FOR ADEQUACY OF WEATHERPROOFING.~~	
17	~~CHECK ANTENNA GUY WIRES FOR LOOSENESS AND PROPER TENSION.~~	
18	~~CHECK TERMINAL BOX COVERS FOR CRACKS, LEAKS, DAMAGED GASKETS, DIRT AND GREASE.~~	
19	~~ELECTRON TUBES — INSPECT FOR LOOSE ENVELOPES, CAP CONNECTORS, CRACKED SOCKETS, INSUFFICIENT SOCKET SPRING TENSION; CLEAN DUST AND DIRT CAREFULLY; CHECK EMISSION OF RECEIVER TYPE TUBES.~~	✓
20	~~INSPECT FILM CUT-OUTS FOR LOOSE PARTS, DIRT, MISALIGNMENT AND CORROSION.~~	
21	INSPECT FIXED CAPACITORS FOR LEAKS, BULGES, AND DISCOLORATION. PAR 27c	✓
22	~~INSPECT RELAY AND CIRCUIT BREAKER ASSEMBLIES FOR LOOSE MOUNTINGS; BURNED, PITTED, CORRODED CONTACTS; MISALIGNMENT OF CONTACTS AND SPRINGS; INSUFFICIENT SPRING TENSION; BINDING OF PLUNGERS AND HINGE PARTS.~~	
23	~~INSPECT VARIABLE CAPACITORS FOR DIRT, MOISTURE, MISALIGNMENT OF PLATES, AND LOOSE MOUNTINGS.~~	
24	INSPECT RESISTORS, ~~BUSHINGS,~~ AND INSULATORS, FOR CRACKS, CHIPPING, BLISTERING, DISCOLORATION AND MOISTURE.	✓
25	INSPECT TERMINALS OF LARGE FIXED CAPACITORS AND RESISTORS FOR CORROSION, DIRT AND LOOSE CONTACTS.	✓
26	CLEAN AND TIGHTEN SWITCHES, ~~TERMINAL BLOCKS, BLOWERS, RELAY CASES,~~ AND INTERIORS OF CHASSIS AND CABINETS NOT READILY ACCESSIBLE. PAR 27d	ⓧ
27	INSPECT TERMINAL BLOCKS FOR LOOSE CONNECTIONS, CRACKS AND BREAKS.	✓
28	~~CHECK SETTINGS OF ADJUSTABLE RELAYS.~~	
29	~~LUBRICATE EQUIPMENT IN ACCORDANCE WITH APPLICABLE DEPARTMENT OF THE ARMY LUBRICATION ORDER.~~	
30	~~INSPECT GENERATORS, AMPLIDYNES, DYNAMOTORS, FOR BRUSH WEAR, SPRING TENSION, ARCING, AND FITTING OF COMMUTATOR.~~	
31	CLEAN AND TIGHTEN CONNECTIONS AND MOUNTINGS FOR TRANSFORMERS, ~~CHOKES, POTENTIOMETERS, AND RHEOSTATS.~~	✓
32	INSPECT TRANSFORMERS, ~~CHOKES, POTENTIOMETERS, AND RHEOSTATS~~ FOR OVERHEATING AND OIL-LEAKAGE. PAR 27e	✓
33	~~BEFORE SHIPPING OR STORING — REMOVE BATTERIES.~~	
34	~~INSPECT CATHODE RAY TUBES FOR BURNT SCREEN SPOTS.~~	
35	~~INSPECT BATTERIES FOR SHORTS AND DEAD CELLS.~~	
36	~~INSPECT FOR LEAKING WATERPROOF GASKETS, WORN OR LOOSE PARTS.~~	
37	~~MOISTURE AND FUNGIPROOF.~~	
38	IF DEFICIENCIES NOTED ARE NOT CORRECTED DURING INSPECTION, INDICATE ACTION TAKEN FOR CORRECTION.	

DA FORM 1 MAY 51 11-239 REPLACES DA AGO FORM 419, 1 DEC 50, WHICH IS OBSOLETE. 16—64382-1

TM5124-10

Figure 10. DA Form 11-239.

(2) Check the summation bridge for normal operation (par. 32).

b. Weekly.

(1) Clean and tighten the panel mountings and knob setscrews.

(2) Inspect exposed metal surfaces of the housing for rust and corrosion. Touch up rusty and corroded spots with corrosion-resistant paint.

(3) Inspect the power cord, test cable, and input cables for breaks, deterioration, and loose connectors.

(4) Inspect Waveguide Probe MX–2144/U for loose connectors, dirt, and cracks in the plastic cover.

(5) Inspect meter M1 for damaged glass or case.

27. Second Echelon Preventive Maintenance

This level of preventive maintenance must be performed by personnel technically trained to perform second echelon maintenance. This maintenance will be performed in accordance with the directions on the reverse side of DA Form 11–239.

a. Perform the maintenance items listed in paragraph 26.

Caution: Disconnect all power from the wattmeter before performing the following operations. Upon completion of these procedures, reconnect the power and check for satisfactory operation of the wattmeter (par. 32).

b. Inspect switches S1 through S5 and controls R30 and R33 for binding, excessive looseness, and for positive action.

c. Inspect fixed capacitor C19 (fig. 20) for leaks or bulging.

d. Clean and tighten switches S1 through S5. All knobs are secured by setscrews. See that the setscrews are tight.

e. Inspect transformer T1 and inductor L2 for evidences of overheating.

Section III. TROUBLESHOOTING AT ORGANIZATIONAL MAINTENANCE LEVEL

28. General

a. Troubleshooting and repairs at the organizational maintenance level are limited only by the tools, materials, test equipment, and replaceable parts authorized at this level. The troubleshooting procedures in this section are arranged to determine first the defective unit, then the nature of the fault within the unit, and finally the applicable corrective measures.

b. Organizational troubleshooting techniques include visual inspection, operational procedures, the use of authorized test equipment, and procedures for sectionalizing troubles to a unit (when more than one unit is involved) and for localizing troubles within a unit.

29. Visual Inspection

a. Failure of this equipment to operate properly usually will be caused by one or more of the following faults:

(1) Worn, broken, or disconnected cords or plugs.

(2) Burned-out fuse.

(3) Wires broken because of excessive vibration.

(4) Defective tubes.

(5) Defective waveguide probe.

b. When failure is encountered and the cause is not immediately apparent, check as many of these items as is practicable before starting a detailed examination of the component parts of the system.

30. Electron Tube Replacement Techniques

To prevent the discarding of good electron tubes, follow the procedures given in *a* through *j* below when troubleshooting Wattmeter AN/URM–98.

a. Inspect all cabling, connectors, and the general condition of the wattmeter before removing the electron tubes.

b. Isolate the trouble, if possible, to a particular circuit of the summation bridge. (Use the equipment performance checklist (par. 32) as a guide.)

c. If a tube tester is available, remove and test one tube at a time. Substitute new tubes only for those that are defective.

d. If a tube tester is not available, troubleshoot the summation bridge by the substitution method.

(1) Replace one of the suspected tubes with a known good tube.

(2) Check to see whether the summation bridge is operative. If the summation bridge is operative, discard the original tube. If the summation bridge is inoperative, remove the new tube and reinsert the original tube.

(3) Continue to check the suspected tubes, using the procedure given in (1) and (2) above, until the summation bridge be-

comes operative or until all the suspected tubes have been checked.

e. If the summation bridge is inoperative after the procedure outlined in *a* through *d* above is completed, continue as follows:

(1) Replace the suspected tubes, one at a time, with known good tubes until the summation bridge becomes operative or until all the suspected tubes are replaced by new ones. Note the sockets from which the original tubes were removed. If the summation bridge begins to operate, discard the last tube removed.

Note. Differential amplifier V1 may function with one tube and not another—even though both tubes are good. If practicable, retain a removed tube until its condition is checked by a suitable test instrument.

(2) Reinsert the remaining original tubes, one at a time, in the original sockets. If the summation bridge fails to operate at any time during this step, discard the original tube last reinserted. *Do not leave a new tube in a socket if the signal generator operates satisfactorily with the original tube.*

Note. If a replacement for a bad tube soon becomes defective, check the adjustment and condition of parts in the tube circuit. Otherwise continued tube replacement will result in only temporary repair, and more serious troubles may result.

f. If the tube substitution does not correct the trouble, *reinsert the original tubes in the original socket* before forwarding the defective summation bridge for higher echelon repair.

g. Discard tubes when—

(1) A test by a tube tester or other instrument shows that they are defective.

(2) The tube defect is obvious. For example, the glass envelope is broken or a connecting prong or lead is broken.

h. Do not discard tubes merely because the tubes have been used for a specified length of time. *Satisfactory operation in a circuit is the final proof of tube quality.* The tube in use may work better than a new one.

i. Do not discard tubes merely because they fall on, or slightly above, the minimum acceptable value when checked in a tube tester. Some new tubes fall near the low end of the acceptable range; yet these tubes may provide satisfactory performance throughout a long period of operational life at this *near limit* value.

j. Be very careful when withdrawing a miniature tube from its socket. *Do not* rock or rotate the top when removing it from its socket—pull straight out. The external pin and the wire lead sealed in the glass base are of two different metals that are butt-welded together where the pin appears to enter the glass. Rocking or rotating the tube causes bending which tends to break this weld or causes a resistance or intermittent joint to develop.

31. Troubleshooting by Using Equipment Performance Checklist

a. General. The equipment performance checklist (par. 32) will help the operator locate trouble. The list gives the item to be checked, the conditions under which the item is checked, the normal indications and tolerances of correct operation, and the corrective measures the operator can take. To use this list, follow the items in numerical sequence.

b. Action or Condition. For some items, the information given in the action or condition column consists of various switch and control settings under which the item is to be checked. For other items it represents an action that must be taken to check the normal indication given in the normal indications column.

c. Normal Indications. The normal indications listed include the visible and audible signs that the operator should perceive when he checks the items. If the indications are not normal, the operator should apply the recommended corrective measures.

d. Corrective Measures. The corrective measures listed are those the operator can make without turning in the equipment for repairs. A reference in the table to higher echelon repair required indicates that the trouble cannot be corrected during operation and that troubleshooting by an instrument repairman is necessary.

32. Equipment Performance Check List

Item No.	Item	Action or condition	Normal indications	Corrective measures
1	Power cord	Plug in power cord, but do not turn line switch ON.		
2	Fuse (F1)	Correct size for line voltage	1 amp for 115 v .5 amp for 230 v.	
3	Power transformer T1.	Correct strapping for line voltage.	See paragraph 11 and figure 25.	
4	Input connector J1	External coaxial cable with waveguide probe connected to other end. BIAS CURRENT switch in OFF position.		
5	BIAS CURRENT switch (S5).	Set to 0—6 MA position.		
6	COEF. POS.-NEG. switch (S2).	Proper position for waveguide probe being used. (NEG. position for MX–2144/U.).	See paragraph 18.	
7	RES. 200–100 switch (S1).	Proper position for waveguide probe used. (200 position for MX–2144/U.).	See paragraph 18.	
8	POWER RANGE switch (S3).	Set to 0 MW position.		
9	ZERO SET:			
	COARSE control (R33).	Set to full clockwise position.		
	FINE control (R30).	Set to full clockwise position.		
10	Line ON switch (S4).	Set to ON position. Allow 5-minute warmup period.	Pilot lamp (I 1) lights.	Check fuse F1 on rear panel. Check line cord and plug. Check for proper strapping on power transformer T1 (par. 11). Replace panel lamp. Higher echelon repair required.
11	MILLIWATTS-DBM meter (M1).	Observe pointer on meter	Pointer on meter should read anywhere on scale or off scale at the high end of meter scale.	If meter pointer reads off scale at low end of meter scale, advance BIAS CURRENT control one step at a time until there is an on scale or high end off scale indication. Check position of COEF. and RES. switches (items 5 and 6 above). Check V6 thru V10. Higher echelon repair required.
12	ZERO SET:			
	COARSE control (R30).	Adjust for as near a zero reading on the meter as possible.		
	FINE control (R33).	Adjust for an absolute zero reading on the meter.	Pointer on MILLIWATTS-DBM meter M1, rests at zero at left-hand end of meter scale.	Check position of COEF. and RES. switches (items 5 and 6 above). Check V1 thru V5. Higher echelon repair required.

CHAPTER 5
THEORY OF OPERATION

33. Block Diagram
(fig. 11)

Wattmeter AN/URM–98 consists of Summation Bridge TS–779/U, Waveguide Probe MX–2144/U, and Cord CG–409/U. It is used for measuring power in radio frequency circuits and microwave systems. Summation Bridge TS–779/U is the major component. This unit contains three functionally distinct circuits: a bridge circuit, a voltmeter circuit, and a power supply. Figure 11 is a block diagram for Summation Bridge TS–779/U and Waveguide Probe MX–2144/U.

a. Bridge Circuit. The bridge circuit is basically an oscillator with a resonant bolometer bridge inserted in the positive feedback loop. The oscillator consists of tubes V1, V2, and V3. When the summation bridge is turned on, noise conditions in the circuit are amplified in differential amplifier tube V1 and passed to bridge amplifier tube V2. The signal is amplified in tube V2 and passed to cathode follower tube V3. Output voltage obtained at the cathode of tube V3 is fed back through the bolometer bridge and applied to the input of tube V1. Feedback voltage is amplified in tubes V1 and V2 and returned to the input of tube V1 from the cathode of V3. Oscillation occurs when the amplified signal from V3 is returned to the input of tube V1. This oscillation frequency of 10.8 kc is determined by a series resonant arm in the bolometer bridge. The bridge circuit has a fixed arm, an adjustable arm, a series resonant arm, and a variable arm. The variable arm is formed by the externally connected Waveguide Probe MX–2144/U. The oscillator generates less power as the bolometer bridge approaches a balanced condition and more power when the bridge is not balanced. The element in the waveguide probe is a temperature-sensitive thermistor. When RF power is applied to the thermistor, the resistance of the thermistor decreases and the bridge is driven toward a balanced condition, thereby attenuating the positive feedback. Consequently, the bridge circuit functions as a 10.8 kc oscillator which generates less power as the element in the waveguide probe is exposed to a stronger field. Output voltage obtained at the cathode of tube V3 is also applied to the voltmeter circuit.

b. Voltmeter Circuit. The voltmeter circuit is basically a vacuum tube voltmeter which monitors the output level of the bridge circuit. The voltage divider circuit associated with POWER RANGE switch S3 adjusts the voltage applied to the voltmeter amplifier circuit. Incoming voltage is amplified by tubes V4 and V5 and passed to meter M1. The polarity of meter M1 is connected so that microwave power readings appearing on the meter scale increase with clockwise deflection of the meter pointer despite the fact that the bridge circuit oscillates with less strength as the RF or microwave power received by the associated waveguide probe increases. This is done by passing current from the B+ supply continuously through the meter in such a direction as to make it deflect clockwise while the rectified oscillator current tends to make it deflect counterclockwise.

c. Power Supply. The power supply furnishes the electrode and filament voltages required by the tubes in the bridge and voltmeter circuits and the current required to make the meter deflect in a clockwise direction. Rectified voltage is supplied to voltage regulator tube V7 by rectifier tube V6. The regulated B+ voltage supplied by tube V7 is governed by the bias on the control grid of the tube. This bias is provided by a two-stage differential amplifier consisting of tubes V8 and V9. B+ voltage obtained at the cathode of tube V7 is passed through a voltage divider network which controls the grid bias of tube V9B. The grid bias of tube V9A is provided by reference tube V10. Tube V9 applies control

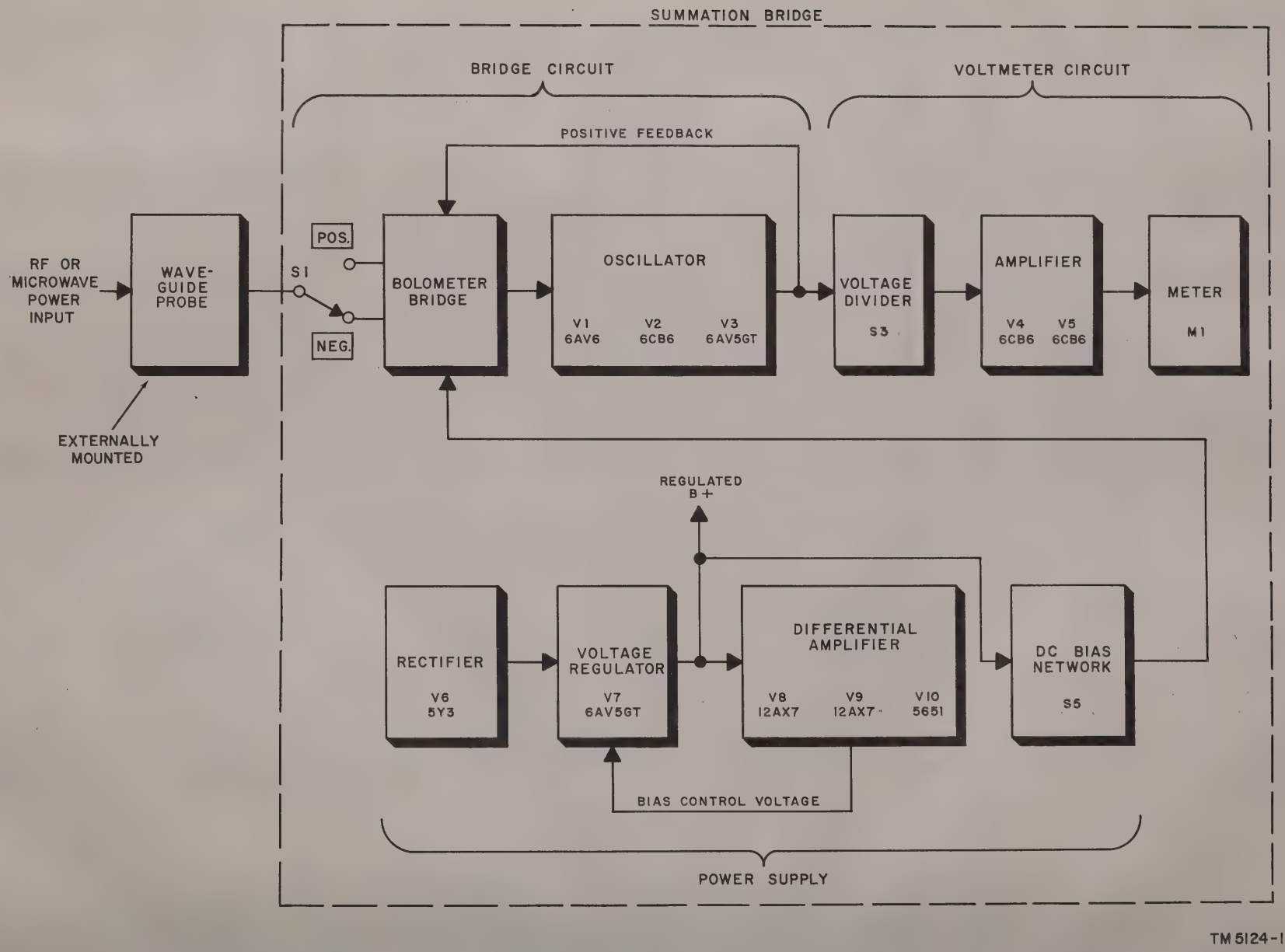


Figure 11. Functional block diagram.

grid bias to both sections of tube V8. When the dc bias voltage at the grids of V9A and V9B are equal, identical plate currents flow in both sections of the tube. When the grid bias voltages of tube V9 are not equal, an error signal in the form of unbalanced plate voltages is supplied by tube V9 to the grids of tube V8. This error voltage is further amplified in tube V8 and impressed as cathode to grid bias on tube V7. This bias voltage varies the dc resistance of tube V7 so that the condition responsible for the existence of the error voltage is counteracted and tube V7 always supplies the same amount of B+ voltage. Regulated B+ voltage from tube V7 is also supplied to a direct-current (dc) bias network associated with BIAS CURRENT switch S5. The dc bias network governs the amount of dc bias current applied as balancing current to the waveguide probe connected to the bridge circuit.

d. Waveguide Probe MX–2144/U. The waveguide probe is connected externally to the summation bridge. It contains two 100-ohm thermistors arranged so that they are in parallel for RF and in series for the dc bias current and 10.8 kc bridge oscillator frequency in the bridge circuit. It is designed to operate in the frequency range from 10 megacycles to 10 kilomegacycles. When connected to the summation bridge, it forms one arm of the bridge circuit. The thermistors are heat sensitive and provide less resistance as the temperature increases. When radiant energy, such as RF or microwave power, is applied to the waveguide probe, the temperature of the thermistors increases and lowers their resistance. This brings the bridge circuit closer to balance which lowers the output of the oscillator, and, in turn, produces a higher meter reading.

34. Bridge Circuit

(figs. 12–15)

The bridge circuit consists of a bolometer bridge and an amplifier that functions as an oscillator. The bolometer bridge controls the output of the oscillator amplifier circuit. When the bolometer bridge is in a state of unbalance, the strength of oscillations increases. As the bolometer bridge becomes closer to balance, the output of the oscillator decreases. A temperature-sensitive element in an externally connected waveguide probe forms one arm of the bolometer bridge and determines the state of bridge balance. The circuit is designed to operate with thermistor type Waveguide Probe MX–2144/U or a barretter type waveguide probe. Thermistor type waveguide probes have a negative temperature coefficient in that resistance decreases as their temperature increases. Barretter type waveguide probes have a positive temperature coefficient in that resistance increases as their temperature increases. A two-position rotary switch (S2) transposes the series resonant arm and the fixed arm of the bridge so that the bridge circuit operates essentially the same for either type operation.

a. Figure 14 is an equivalent-circuit diagram showing the arrangement of the bridge circuit for thermistor operation. In this arrangement, positive feedback from cathode follower tube V3 is applied to the bolometer bridge at the junction of the fixed and adjustable arms. A portion of the positive feedback is applied across the grid and cathode of tube V1 from the bridge output. The grid and cathode circuits are composed of the variable arm and the series resonant arm.

b. Figure 15 is an equivalent-circuit diagram showing the arrangement of the bridge circuit for barretter operation. In this arrangement, positive feedback from cathode follower tube V3 is applied to the bolometer bridge at the junction of the series resonant and adjustable arms. A portion of the positive feedback is applied to the grid of tube V1 at the junction of the adjustable and variable arms and to the cathode of tube V1 at the junction of the fixed and series resonant arms.

c. Switch S1 is used to adjust the adjustable arm of the bridge to maintain the proper bridge arm impedance relationship with the variable arm. It is set in the 100 position when waveguide probes with 100-ohm internal resistance are used and in the 200 position when waveguide probes with 200-ohm internal resistance are used.

d. Figure 12 is a simplified schematic diagram of the bolometer bridge circuit and figure 13 is a simplified schematic diagram of the oscillator circuit. When the summation bridge is turned on, switching transients and electrical noise are produced in oscillator tubes V1, V2 and V3. This noise shock excites reactor L1 and capacitors C3 and C4 in the bolometer bridge producing damped oscillations at the resonant frequency of 10.8 kc. These signals are passed through coupling capacitors C5 and C6 to both the grid and the cathode of differential amplifier tube V1 in the oscillator. At tube V1, dc bias voltage is developed across resistor R13 and applied to the control grid through the series combination of resistors R11

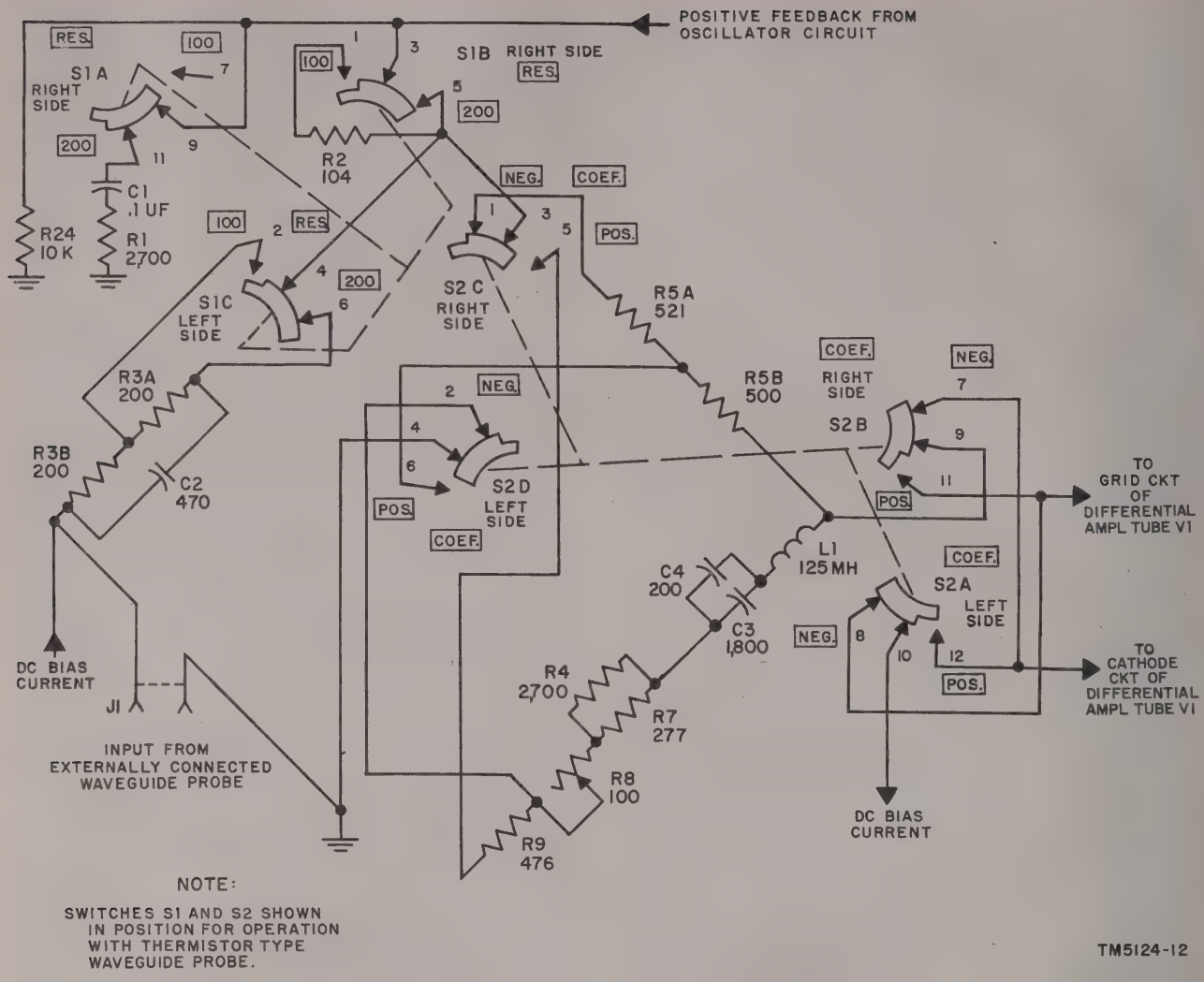


Figure 12. Bolometer bridge circuit, simplified schematic diagram.

and R12. Resistors R11 and R12 form the grid return resistance. Resistor R14 and capacitor C7 improve the phase-gain characteristics of the amplifier. Plate load for tube V1 is provided by resistor R10.

e. The amplified output of tube V1 is passed to bridge amplifier tube V2 through a coupling network consisting of capacitors C8 and C9 and resistors R15 and R35. Capacitor C9 provides ac coupling and dc isolation between the plate of tube V1 and the grid of tube V2. Resistor R15 is the grid return resistor for tube V2. Capacitor C8 improves the phase-gain characteristics of the amplifier. Resistor R35 is a limiting resistor to prevent overloading of tube V2. Operating grid bias for tube V2 is provided by resistor R18. Resistors R16 and R17 form a plate load resistance for tube V2. Capacitor C10 bypasses higher frequences and generally improves the phase-gain characteristics of the amplifier. Screen grid voltage is supplied by a voltage divider network consisting of resistors R19 and R20.

f. The amplified output of tube V2 is coupled to cathode follower tube V3 through capacitor C11. Resistor R21 is the grid return and resistor R22 provides the dc bias for tube V2. Resistor R23 limits the dc current through this tube. Positive feedback voltage is obtained at the cathode of tube V3 and passed through dc block capacitor C12 to the bolometer bridge and returned to the input of tube V1. The positive feedback voltage reinforces the original 10.8 kc signal. The reinforced signal is again amplified in the oscillator amplifier and returned to the input. This cycle of events is cumulative resulting in a rapid buildup of the level of the 10.8 kc

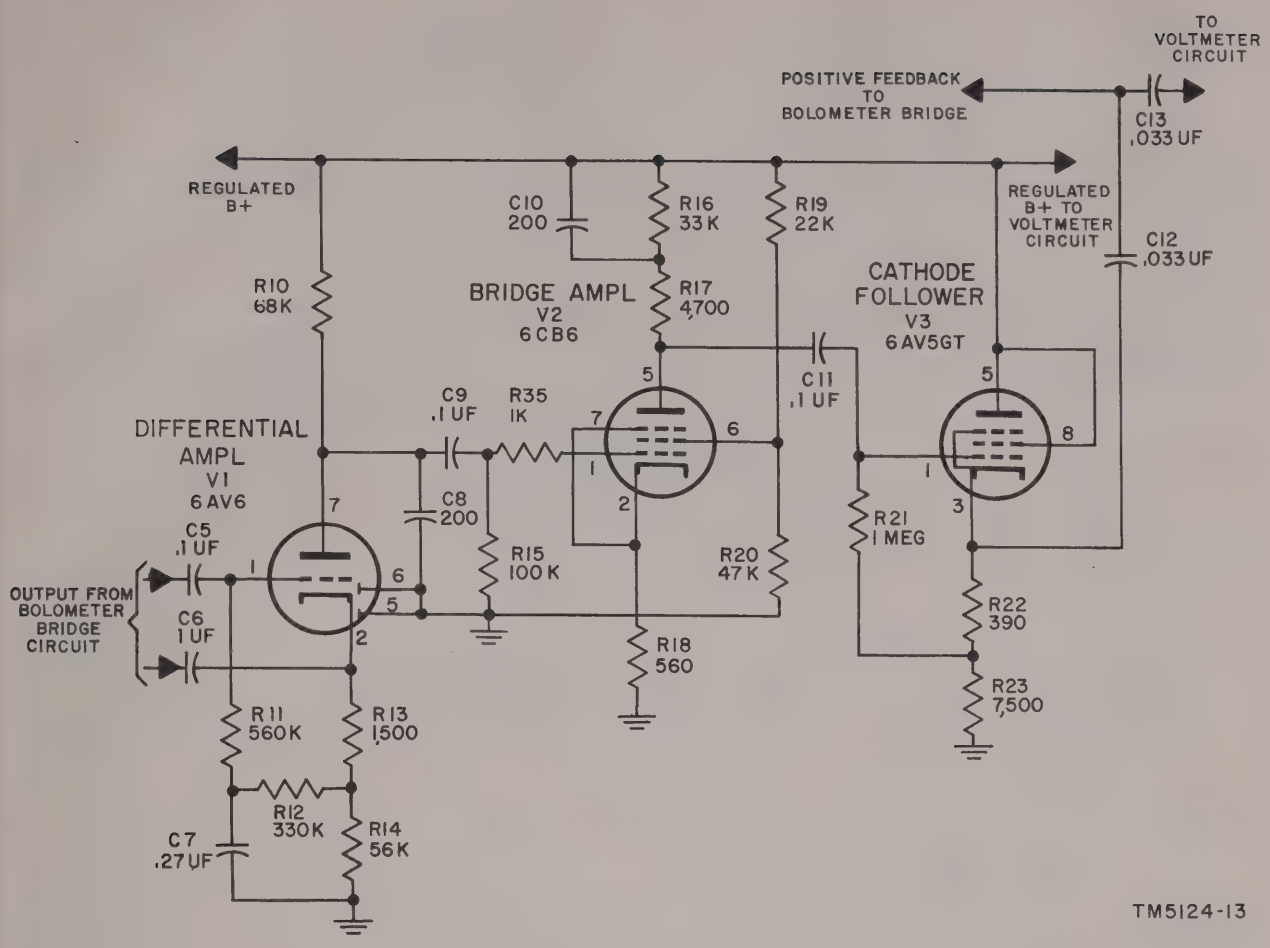


Figure 13. Oscillator amplifier circuit, simplified schematic diagram.

signal. The amplitude attains a level determined by the limiting characteristics of the tubes, and self-sustained oscillations exist.

g. The bolometer bridge balance is determined by the effective impedances of the four arms of the bridge. At resonance, reactor L1 and capacitors C3 and C4 have low impedance. Therefore, the impedance of the series resonant arm of the bridge is governed by resistors R4, R7, R8 and R9. Resistor R8 is used to adjust the impedance of this arm of the bridge.

h. Elements in the waveguide probes have either a 100- or 200-ohm resistance. Switch S1 is used to adjust the adjustable arm of the bolometer bridge for operation with either 100- or 200-ohm bolometer elements. When a 100-ohm bolometer element is used, switch S1 is set to the 100 position. This removes capacitor C2 and resistor R3A from the circuit. In this switching position, resistor R3B forms this arm of the bridge and resistor R2 is brought into the bridge circuit to limit the feedback voltage from the oscillator. This preserves operating conditions identical with the 200 switch position operation. When switch S1 is in the 200 position, resistors R3A and R3B and capacitor C2 are connected to form the adjustable arm of the bridge and resistor R2 is removed from the circuit.

i. The fixed arm of the bolometer bridge consists of resistors R5A and R5B. When the summation bridge is being operated with a waveguide probe having a negative temperature coefficient (thermistor type), both resistor R5A and R5B are brought into the circuit through the switching action of switch S2. When a waveguide probe with a positive temperature coefficient is being used (barretter type), switch S2 is turned to the POS. position and resistor R5A is removed from circuit. In this position, resistor R5B forms the fixed leg of the bridge. When switch S2 is in the NEG. position, feedback voltage from tube V3 is applied to the bridge at the junction

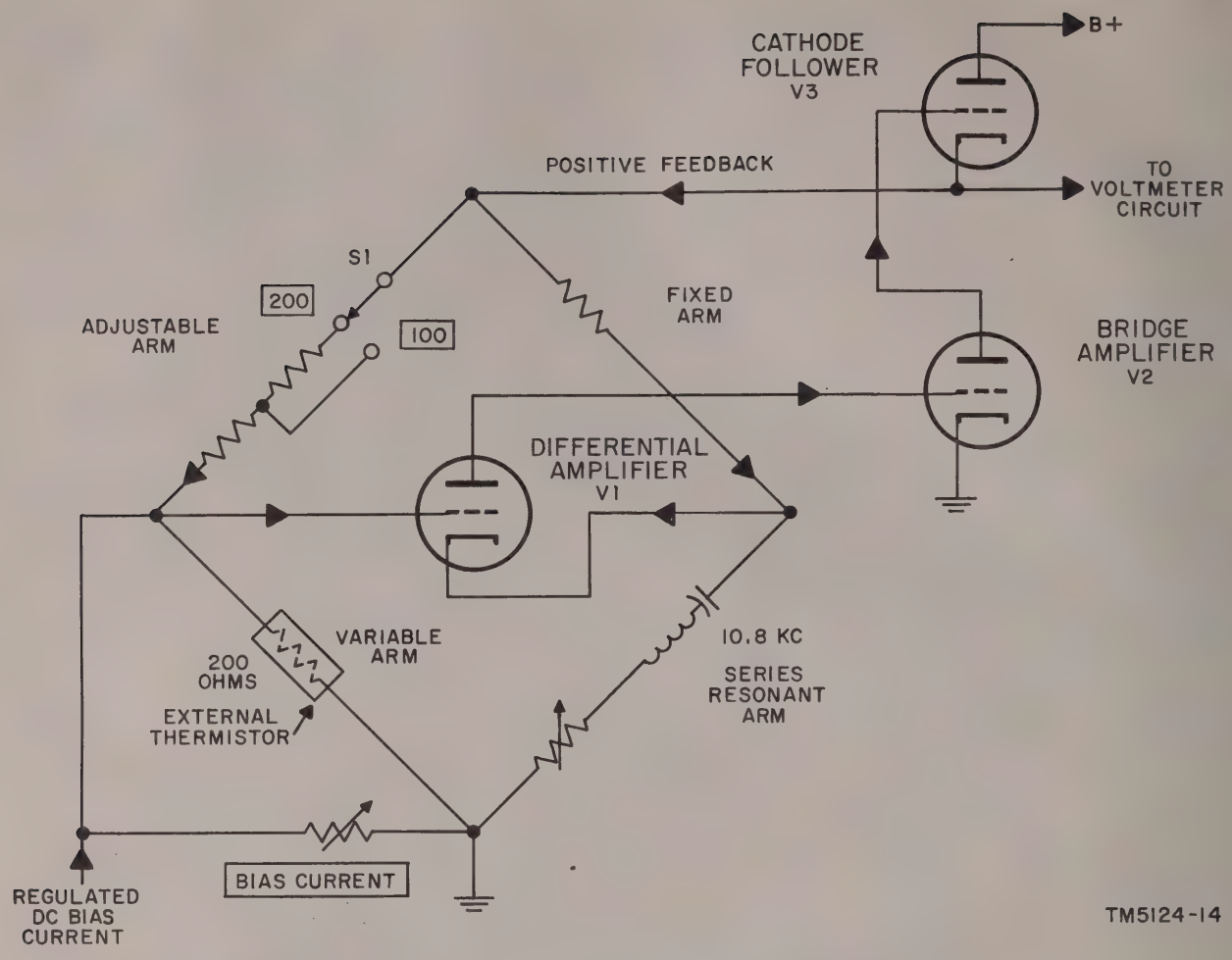


Figure 14. Bridge circuit using thermistor type waveguide probe, equivalent-circuit schematic diagram.

of the adjustable and fixed arms. When switch S2 is in the POS. position, the relative positions of the fixed and series resonant arms of the bridge are transposed and feedback voltage from tube V3 is applied to the bridge at the junction of adjustable and series resonant arms. Transposing the series resonant and fixed arms allows the bridge to always be driven toward a balanced condition when the bolometer element in the waveguide probe is heated. Switching of S2 also interchanges the grid and cathode connections of tube V1 to maintain proper phase conditions for either negative or positive bolometer elements.

j. The variable arm of the bolometer bridge is formed by an externally connected waveguide probe. The elements in the waveguide probe may be either thermistor or barretter type. The thermistor type has a negative temperature coefficient so that heating the thermistor decreases its resistance. The barretter type has a positive temperature coefficient so that heating the barretter increases its resistance. For thermistor type operation, a decrease in resistance drives the bridge closer to balance. For barretter type operation, an increase in resistance drives the bridge closer to balance.

k. Feedback energy developed by the oscillator is passed through the adjustable arm of the bridge to the variable arm (fig. 14). Dc bias current is supplied to the bridge circuit from the power supply. This dc bias current is adjustable by panel controls BIAS CURRENT, S5, ZERO SET-COARSE (R33), and ZERO SET-FINE (R30) (fig. 18). The dc bias current, in conjunction with the ac feedback current from the oscillator, raises the operating temperature of the bolometer element in the waveguide probe (fig. 14). This drives the bridge closer to a balanced condition. As the bridge approaches a balanced condition, the output level of the oscillator

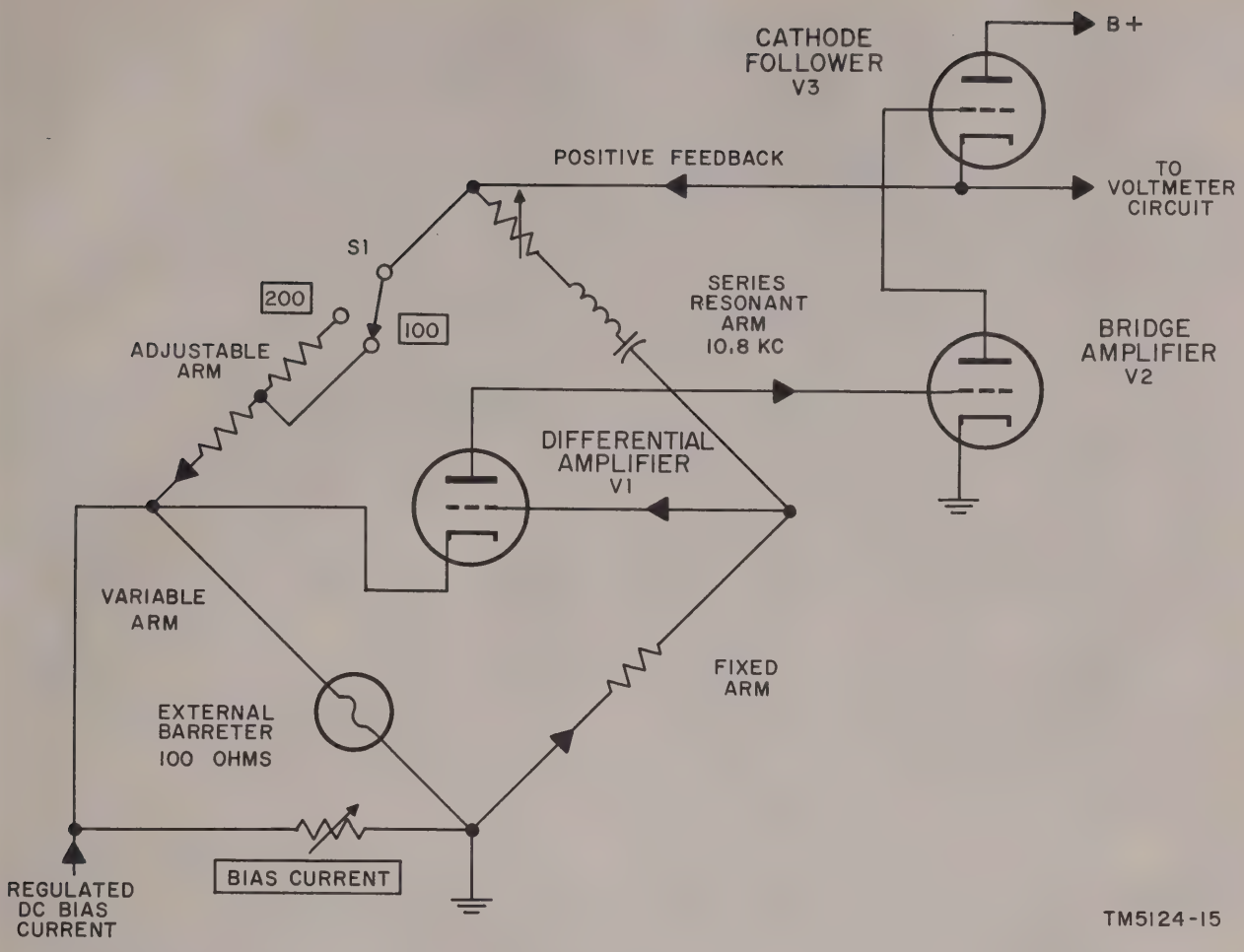


Figure 15. Bridge circuit using barretter-type waveguide probe, equivalent-circuit schematic diagram.

decreases. The dc bias current is adjusted so that when no source of RF or microwave power is applied to the bolometer element, a near state of bridge balance is attained. Specifically, a degree of balance is obtained which corresponds to an arbitrary zero reading on meter M1 in the voltmeter circuit. In this way, the effect of the surrounding air temperature upon the bolometer element is circumvented.

l. Resistor R24 in the bolometer bridge circuit dissipates excessive 10.8 kc oscillatory power when the bridge is extremely unbalanced. This condition exists when the summation bridge is turned on and the waveguide probe is not connected into the bolometer bridge.

m. Resistor R1 and Capacitor C1 in the bolometer bridge circuit absorb switching transients produced by the actuation of switch S1.

35. Voltmeter Circuit
(fig. 16)

a. Figure 16 is a simplified schematic diagram of the voltmeter circuit. A 10.8 kc input signal is supplied to the voltmeter circuit from the cathode of tube V3 in the oscillator circuit. This input voltage is passed through coupling capacitor C13 to an adjustable voltage divider network consisting of multisection resistor R49 in conjunction with POWER RANGE switch S3A. Resistor R49 adjusts the applied voltage to the voltmeter circuit and enables measurements to be made over different amplitude ranges.

b. The adjusted voltage is passed through limiting resistor R54 to the control grid of tube V4. Dc operating bias for tube V4 is supplied by the series combination of resistors R57, R58, and R59. Resistor R55 provides the plate load and

resistor R56 is the voltage dropping resistor for the screen grid of tube V4. Capacitor C15 is the screen grid bypass capacitor for tube V4.

c. The output of tube V4 is coupled through capacitor C14 to the control grid of second amplifier tube V5. Plate load for tube V5 is provided by resistor R61. Resistor R60 is the grid return resistance and resistor R62 provides dc operating bias for tube V5.

d. The output of V5 is coupled through capacitor C16 to a diode bridge consisting of rectifiers CR1, CR2, CR3, and CR4. Negative feedback is derived from the output of tube V5 at the junction of rectifiers CR3 and CR4. This feedback is applied through capacitor C18 to variable resistor R58 in the input circuit of first amplifier tube V4. ZERO ADJ. resistor R58 is used to adjust the amount of negative feedback and therefore the overall gain of the two-stage amplifier circuit. Meter M1 is connected between the junction of rectifiers CR1 and CR3 and the junction of rectifiers CR2 and CR4. This connection provides full-wave rectification of the 10.8 kc signal for application to the meter.

e. Resistors R64 and R65 supply a residual dc bias current to the meter. The polarity of the meter is connected so that the dc bias current drives the pointer on the meter towards full scale deflection. The rectified 10.8 kc signal appears at the meter terminals in opposite polarity from that of the dc bias current and tends to drive the pointer on the meter toward a zero or left-hand deflection. F. S. ADJ. R63 is used to adjust the full scale reading of the meter by diverting part of the dc current applied to the meter. Since the dc bias current always remains at a fixed value, the higher the output level of the bridge circuit, the more the pointer on the meter moves toward zero. Exact zeroing of the meter is accomplished through adjustment of the BIAS CURRENT control S5, ZERO SET-COARSE (R33), and ZERO SET-FINE (R30) (fig. 25). These controls adjust the amount of dc bias current supplied to the waveguide probe connected to the bolometer bridge circuit.

f. The amount of bias current that flows through the bolometer element of the bridge is determined by BIAS CURRENT switch S5 and the ZERO SET controls. It is not necessary to have an exactly calibrated setting of switch S5 because this is adjusted by the ZERO SET controls. The purpose of S5 is to get the bias current in a range that can be controlled by the ZERO SET controls. For this reason, only a rough calibration of the switch is given. The steps in switch S5 are used to give rough estimates of the amount of bias current needed. If the meter reads off scale at the low end, switch S5 is moved in a clockwise direction until the meter reads on scale. If the meter reads off scale on the high end and cannot be zeroed by the ZERO SET controls, switch S5 is moved in a counterclockwise direction until the meter can be zeroed regardless of the setting of switch S5.

g. The meter is deflected clockwise by the current obtained through resistors R64 and R65. It is deflected counterclockwise by the rectified feedback voltage supplied by the vacuum tube voltmeter circuit. The result is that as RF or microwave power is applied to the waveguide probe, it heats the element which drives the bridge closer to balance. When the bridge approaches balance, it decreases the output level from the oscillator. The lower the output level from the oscillator, the greater the clockwise deflection of the meter (a higher meter reading is obtained).

36. Power Supply

(fig. 17)

a. The power supply is designed to operate from either a 115- or 230-volt, 50- to 1000-cycle-per-second (cps), ac power source. Power transformer T1 has strapping options for the type of line voltage used. Full wave rectification of the transformer voltage is provided by rectifier tube V6 (fig. 25). The resultant dc voltage is applied to series regulator tube V7 (fig. 17). The dc voltage output of tube V7 is determined by the resistance the tube offers to passage of current. The effective dc resistance of tube V7 is controlled by bias voltage impressed at its control grid. This control bias is provided by a differential amplifier circuit consisting of tubes V8, V9 and V10. Figure 17 is a simplified schematic diagram of the power supply differential amplifier and voltage regulating circuits.

b. B+ voltage obtained at the cathode of tube V7 is divided by a voltage divider composed of resistors R74, R75, and R76 and applied as grid bias to tube V9B. Variable resistor R75 is used to adjust the amount of voltage applied to the grid tube V9B. Capacitor C21 is used to speed up the regulating process by coupling changes in the B+ voltage to the grid of tube V9B.

c. Grid bias voltage for tube V9A is obtained from reference tube V10 through limiting resistor

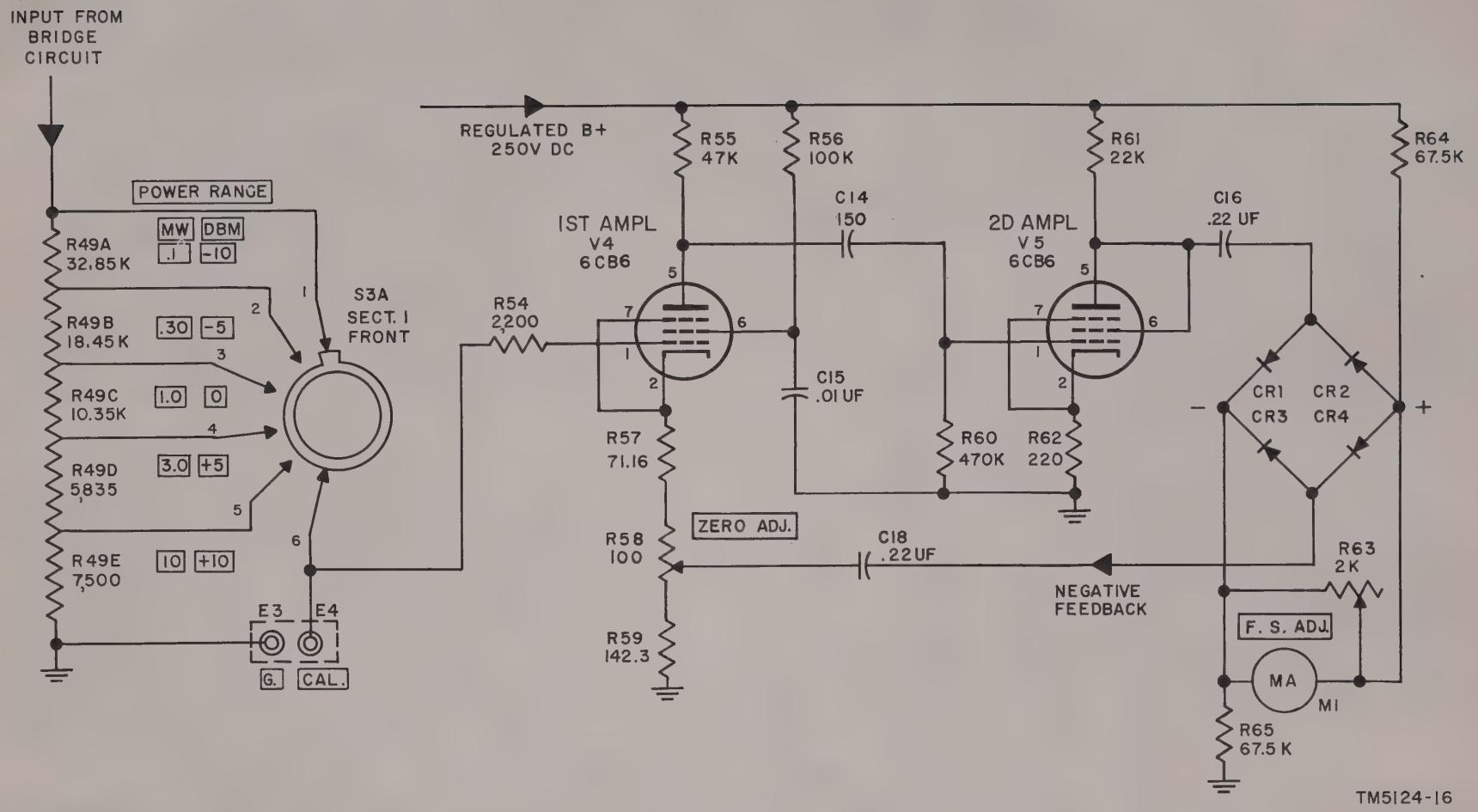


Figure 16. Voltmeter circuit, simplified schematic diagram.

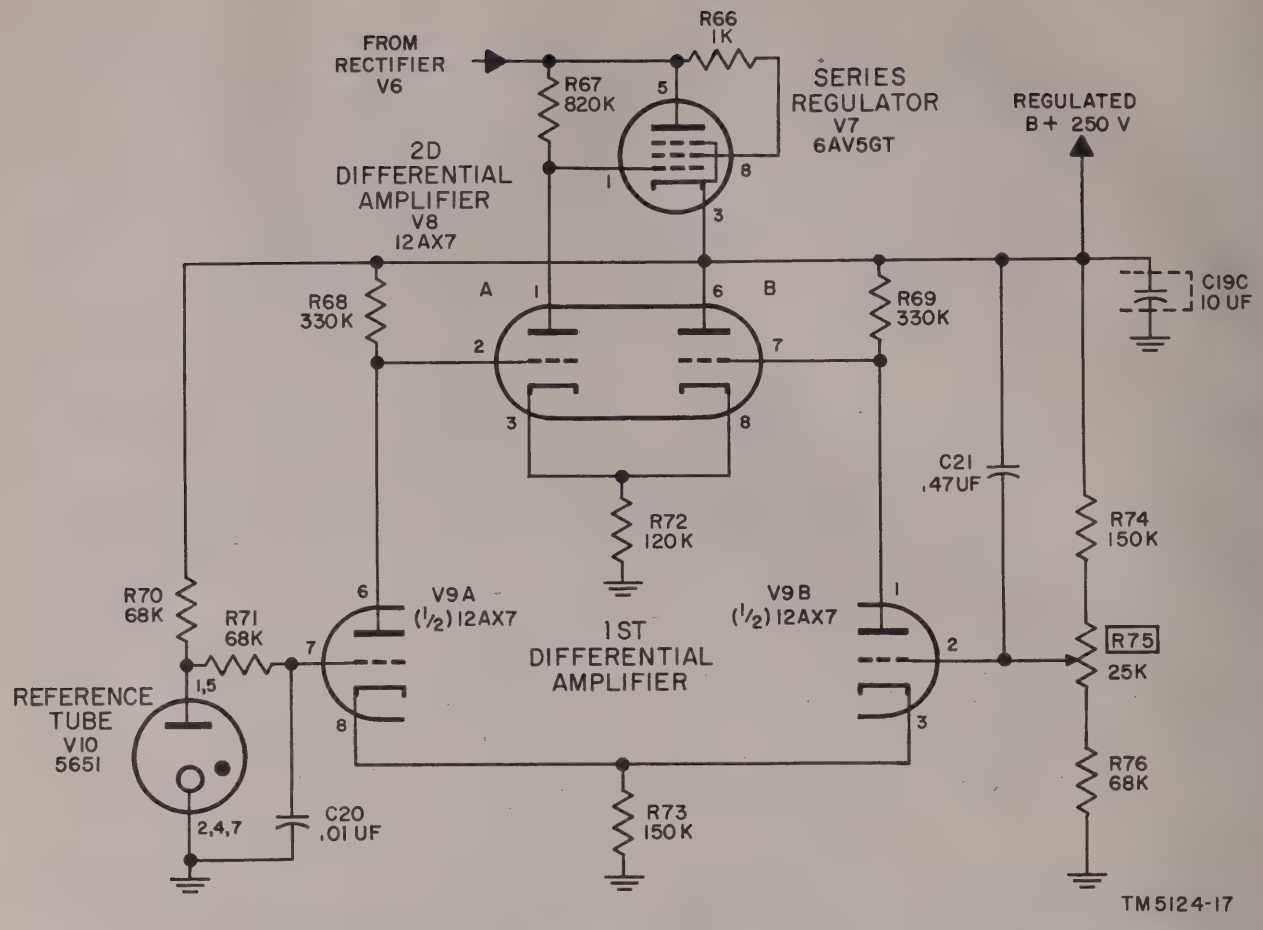


Figure 17. Power supply differential amplifier and voltage regulating circuits, simplified schematic diagram.

R71. Operating current for tube V10 is derived through resistor R70 from the cathode of tube V7. Capacitor C20 bypasses spurious signals generated by the ionization of tube V10. Resistor R73 is a mutual cathode resistor for the cathodes of tubes V9A and V9B. The voltage drop across resistor R73 develops negative grid bias for both sections of tube V9. The value of this grid bias is high enough so that the grid bias voltages are always negative despite the fact that positive grid bias voltage is supplied from tube V10 and voltage divider R75. Resistor R73 also provides dc degeneration which stabilizes the operation of tube V9. Plate lead for tube V9A is supplied by resistor R68 and plate load for tube V9B is supplied by resistor R69.

d. When the dc bias voltage on the grids of V9A and V9B are equal, identical plate currents flow in these tube sections. Output voltage from tubes V9A and V9B are applied as control grid bias to the grids of tube sections V8A and V8B respectively. Resistor R72 is a mutual cathode bias resistance for both sections of tube V8. This resistance always maintains the net grid bias voltages of tube V8 in the negative region. Resistor R72 also provides dc degeneration which stabilizes the operation of tube V8. Resistor R67 provides plate load for tube section V8A.

e. The grid to cathode voltage of tube V7 is governed by the relative conductive states of tubes V8A and V8B. Voltage applied to the grid and cathode of tube V7 from tube V8 varies the effective resistance of tube V7 and therefore, the voltage available at the output of tube V7. The change in resistance in tube V7 is always in such a direction that it counteracts the B+ voltage condition causing it.

f. Resistor R66 is the screen grid voltage dropping resistor for tube V7. Filtering of the regulated B+ voltage is provided by capacitor C19C.

CHAPTER 6

FIELD MAINTENANCE

Note. This chapter contains information for field maintenance. The amount of repair that can be performed by units having field maintenance responsibility is limited only by the tools and test equipment available and by the skill of the repairman.

Section I. TROUBLESHOOTING AT FIELD MAINTENANCE LEVEL

Warning: Certain points located throughout the chassis of the summation bridge operate at voltages above 250 volts. Do not touch these points while power is being applied to the summation bridge. Be very careful when handling or testing any part of the summation bridge while it is connected to the power source.

37. Troubleshooting Procedures

a. General. The first step in servicing a defective summation bridge is to sectionalize the fault. Sectionalization means tracing the fault to one of the three major circuits responsible for the abnormal operation: the bridge circuit, the vacuum tube voltmeter circuit, or the regulated power supply circuit. The second step is to localize the fault. Localization means tracing the fault to a particular stage or network within one of the three major circuits. The third step is to isolate the fault. Isolation means tracing the fault to the defective part responsible for the abnormal condition. Some faults, such as burned-out resistors, arcing, and shorted transformers, often can be located by sight, smell, and hearing. The majority of faults, however, must be isolated by checking voltages and resistances.

b. Component Sectionalization, Localization, and Isolation. Listed in (1) through (4) below is a group of tests arranged to simplify and reduce unnecessary work and aid in tracing a trouble to a specific component. Follow the procedure in the sequence given. A serviceman must be careful to cause no further damage to the wattmeter while it is being serviced.

(1) *Visual inspection.* The purpose of visual inspection (par. 29) is to locate any visible trouble. Through inspection alone, the repairman frequently may discover the trouble or determine the circuit in which the trouble exists. This inspection is valuable in avoiding additional damage to the summation bridge which occurs through improper servicing methods and in forestalling future failures.

(2) *Equipment Performance Checklist.* The equipment performance checklist (par. 32) is important because it indicates the general location of trouble. In many instances, the information gained will determine the exact nature of the fault. To utilize this information fully, all symptoms must be interpreted in relation to one another.

(3) *Troubleshooting Chart.* The trouble symptoms listed in this chart (par. 42) will aid greatly in locating trouble.

(4) *Intermittents.* In all these tests, possibility of intermittent conditions should not be overlooked. If present, this type of trouble often may be made to appear by tapping or jarring the equipment. It is possible that some external connections may cause the trouble. Test wiring for loose connections and move wires and components with an insulated tool, such as a pencil or fiber rod. This may show where a faulty connection or component is located.

38. Troubleshooting Data

Fig. No.	Par. No.	Title
4	____	Tube location.
18	____	Summation bridge, B+ voltage distribution.
19	____	Summation bridge, right-hand side view of chasis.
20	____	Summation bridge, left-hand side view of chassis.
21	____	Terminal board voltage and resistance diagram.
22	____	Tube socket voltage and resistance diagram.
24	____	Waveguide Probe MX–2144/U.
25	____	Summation Bridge TS–779/U, schematic diagram.
26	____	Summation Bridge TS–779/U, wiring diagram.
	43	Dc resistances of transformers and coils.

39. Test Equipment Required

The items of test equipment required for troubleshooting Wattmeter AN/URM–98 are listed below. Technical manuals and common names associated with each item are also listed.

Test equipment	Technical manual	Common name
Tube Tester TV–7/U	TM 11–5083	Tube tester.
Voltmeter Meter ME–30A/U.	Literature packed with equipment.	Vtvm.
Multimeter TS–352/U	TM 11–5527	Multimeter.

40. General Precautions

Observe the following precautions very carefully whenever servicing the wattmeter:

a. Be careful when the summation bridge is removed from the housing; dangerous voltages are exposed.

b. If the summation bridge has been operating for some time, use a cloth when removing metal tube clamps and a tube puller to remove the tubes to prevent burning the hand or fingers.

c. When servicing the chassis assembly, do not disturb the settings of the variable resistors located on the chassis, R8, R58, R63, and R75 (figs. 19 and 20).

d. Do not overtighten screws when assembling mechanical couplings.

e. When changing a component that is held by screws, always replace the lockwashers.

f. Careless replacement of parts often makes new faults inevitable. Note the following points:

(1) Before a part is unsoldered, note the position of the leads. If the part, such as a power transformer, has a number of connections, tag each lead.

(2) Be careful not to damage other leads by pushing or pulling them out of the way.

(3) Do not use a large soldering iron when soldering small resistors or ceramic capacitors. Overheating of the small parts may ruin the component or change its value.

(4) Do not allow drops of solder to fall into parts of the chassis because they may cause short circuits.

(5) A carelessly soldered connection may create new faults. It is very important to make well-soldered joints because a poorly soldered joint is one of the most difficult faults to find.

(6) Replace parts in the circuit in exactly the same position occupied by the original part. A part that has the same electrical value but different physical size may cause trouble. Give particular attention to proper grounding when replacing a part; use the same ground as in the original wiring. Failure to observe these precautions may result in decreased output or parasitic oscillations.

(7) *Do not disturb* any of the alinement adjustments unless it definitely has been determined that the trouble is caused by an adjustment.

41. Checking Filament and B+ Circuits for Shorts

a. After the B+ leaves series regulator tube V7, it is directly distributed to all circuits. Refer to figure 18, which is a simplified diagram of the B+ distribution throughout the summation bridge and the possible paths which could offer short circuits or excessive loading. By using this diagram in conjunction with the voltage and resistance measurements (figs. 21 and 22) the typical cause of trouble can be checked.

b. The power-supply output voltage at pin 3 of tube V7 should be 250 volts. Normally, if the output voltage is low, the trouble will be in the power-supply circuit. If tubes V6 and V7 are defective or if any section of capacitor C19 shorts, and the fuse does not blow, the output voltage of the power supply will be low. If tubes V8, V9, or V10 are defective, normally the output voltage from the power supply will be high. If section C of capacitor C19 shorts, tube V10 will go out. If

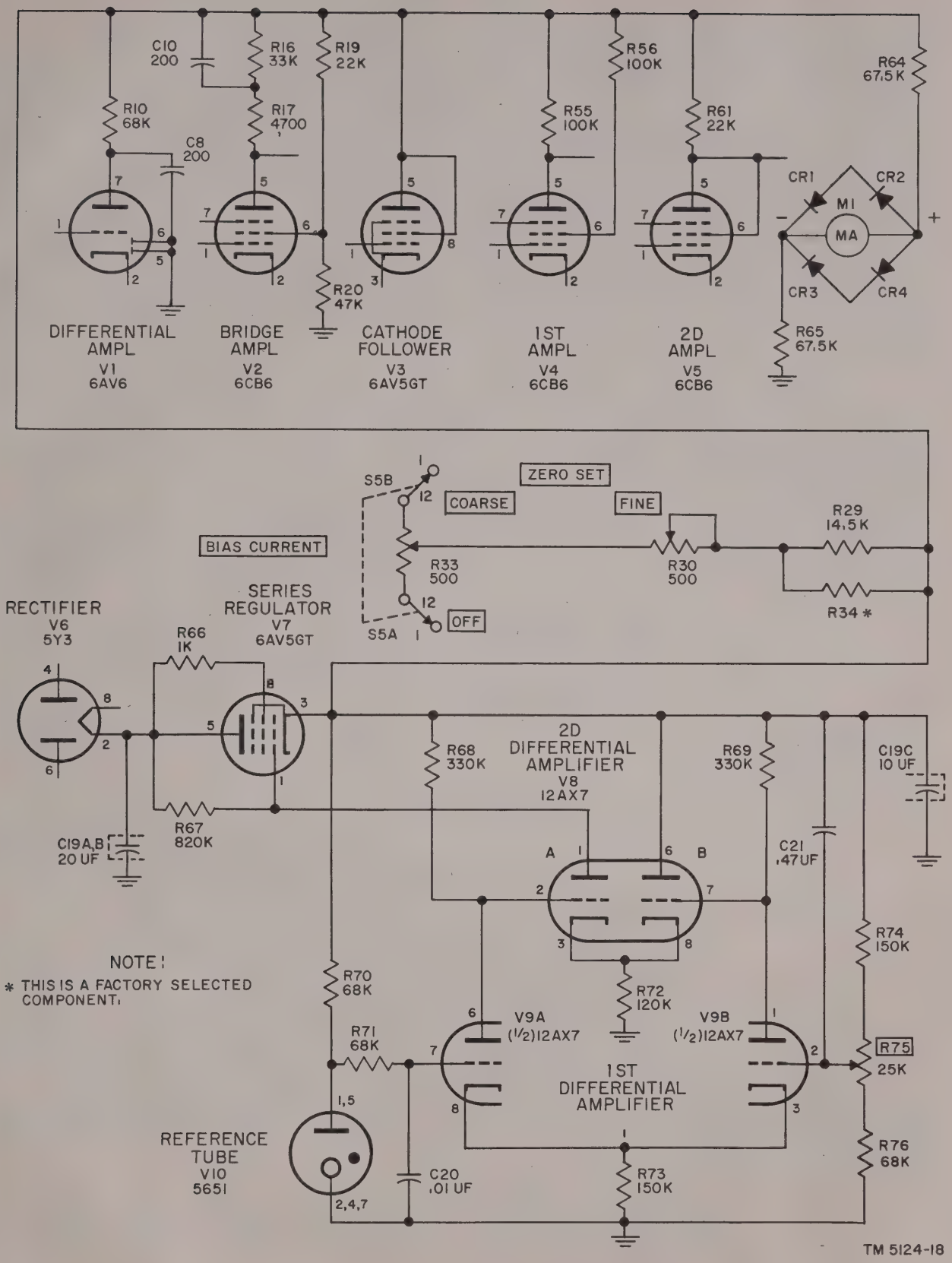


Figure 18. Summation bridge, B+ voltage distribution.

the output voltage is erratic, tube V10 is defective. If the output voltage of the power supply at pin 3 of tube V7 is not 250 volts exactly, adjust variable resistor R75 until the proper reading is obtained.

c. In the oscillator circuit, excessive power-supply loading would exist if capacitor C10 shorts or if tube V3 becomes defective. A trouble in any circuit will be noticed when following the operating procedures in paragraphs 18 through 20. These troubles will be indicated in the equipment performance checklist (par. 32). Most of the checking can be accomplished from the left-hand side of the chassis.

42. Troubleshooting Chart

The following chart is supplied as an aid in locating trouble in the wattmeter. It lists the symptoms which the repairman observes, either visually or audibly, while making a few simple tests. The chart also indicates how to sectionalize trouble quickly to the bridge, voltmeter, or power-supply circuits. After the trouble has been localized to a stage, a tube check and voltage and resistance measurements of this stage ordinarily should be sufficient to isolate the defective parts. Normal voltage and resistance readings are given in figures 21 and 22.

Symptom	Probable trouble	Correction
Line cord connected to power source and power switch is in the ON position. The pilot lamp does not light.	Defective lamp I 1. Fuse F1 blown.	Replace lamp. Refer to symptom 2.
Line cord connected to power source and power switch in the ON position. Fuse F1 blows.	Transformer T1 not strapped properly.	Replace blown fuse F1. If fuse blows again, check terminal strapping of transformer T1 (par. 11). Check for proper size fuse. Fuse should be 1 ampere for 115-volt operation and .05 ampere for 230-volt operation.
	Defective rectifier tube V6	Check tube and replace if defective.
	Defective line cord or plug	Check line cord and plug and replace if defective. Check for proper voltage at P1.
	Defective filter capacitor C19A, C19B, or C19C.	Check capacitor and replace if defective.
External waveguide probe connected to input connector J1. Meter needle deflects to the right of zero MW and cannot be zero set (par. 19).	Defective waveguide probe	Check the waveguide probe (fig. 24 and par. 46). Replace if defective. Check associated interconnect cable assembly.
	Defective power supply tube V8 or V9.	Check the voltage at pin 3 of tube V7. It should be 250 volts. Adjust variable resistor R75 (fig. 19) if necessary until the 250-volt reading is obtained. Check the power-supply circuit (par. 41).
	Defective oscillator tube V1, V2 or V3.	Check tubes and replace if defective.
	Defective voltmeter tube V4 or V5.	Check tubes and replace if defective.
	Defective meter M1	Replace if defective.
	Voltmeter circuit not adjusted properly.	Adjust voltmeter circuit (par. 49b).
	Defective switch contacts on S1, S2, S3, or S5.	Check switches. Clean contacts. Check for broken wires. Replace defective parts.
	Dc bias, circuit defective	Check bias circuit (par. 44).
External waveguide probe connected to input connector J1. Meter needle deflects to left of zero MW and cannot be zero set (par. 19).	Defective waveguide probe	Check the waveguide probe (fig. 24 and par. 46). Replace if defective. Check associated interconnect cable assembly.
	Defective resistor R64 or R65	Check resistors and replace if defective. (fig. 21).
	Defective power supply tube V6 or V7.	Check tubes and replace if defective. Check power supply circuit (par. 41).

Symptom	Probable trouble	Correction
	Variable resistors R63 or R58 not adjusted properly.	Check adjustment of variable resistors (par. 49*b*).
	Defective switches S1, S2, S3, or S5.	Check switches. Clean contacts. Check for broken wires. Replace defective parts.
	Variable resistors R30 or R33 defective.	Check variable resistors. Replace if defective.
	Dc bias circuit defective-----	Check dc bias circuit (par. 44).

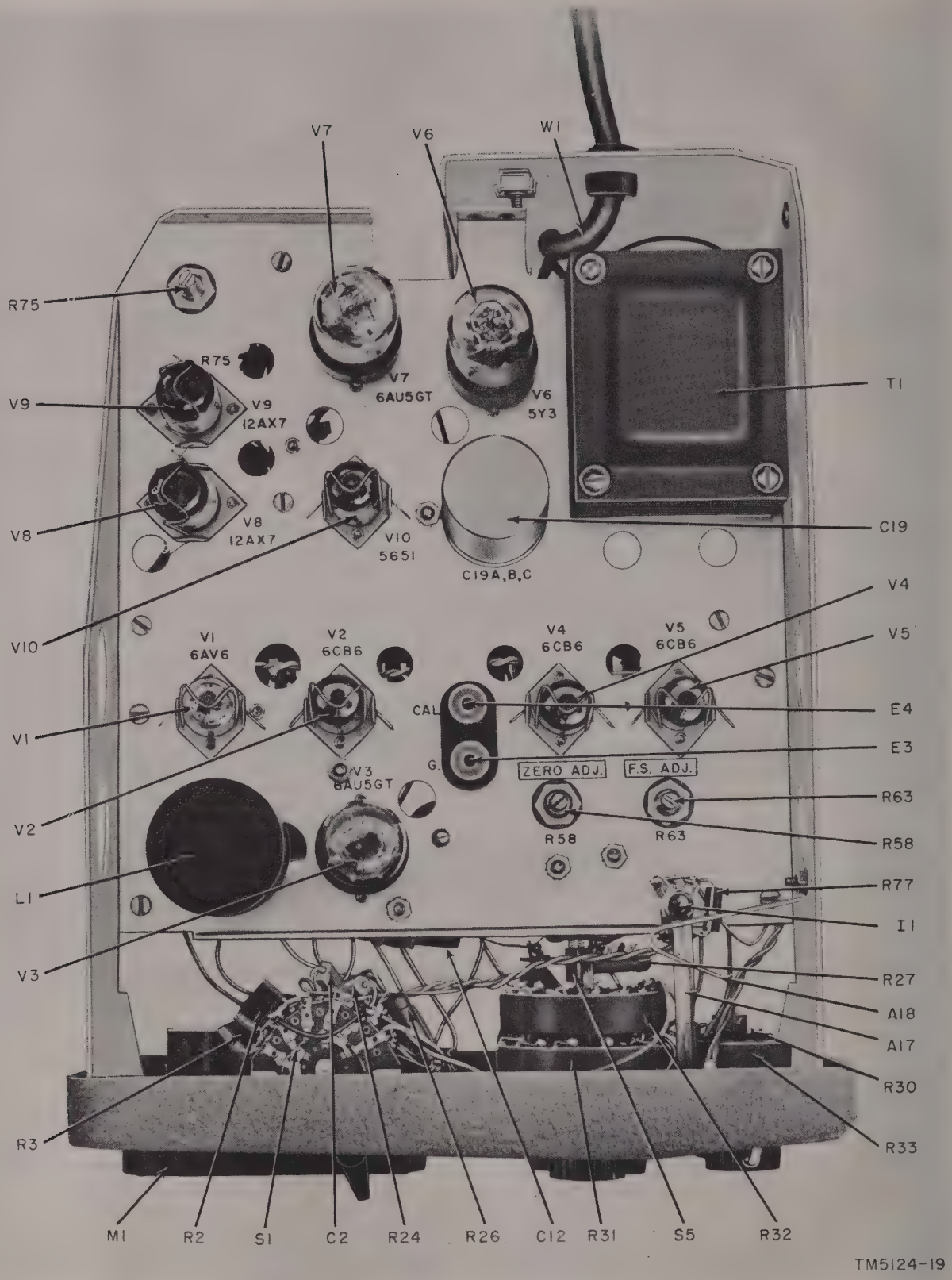


Figure 19. Summation bridge, right-hand side view of chassis.

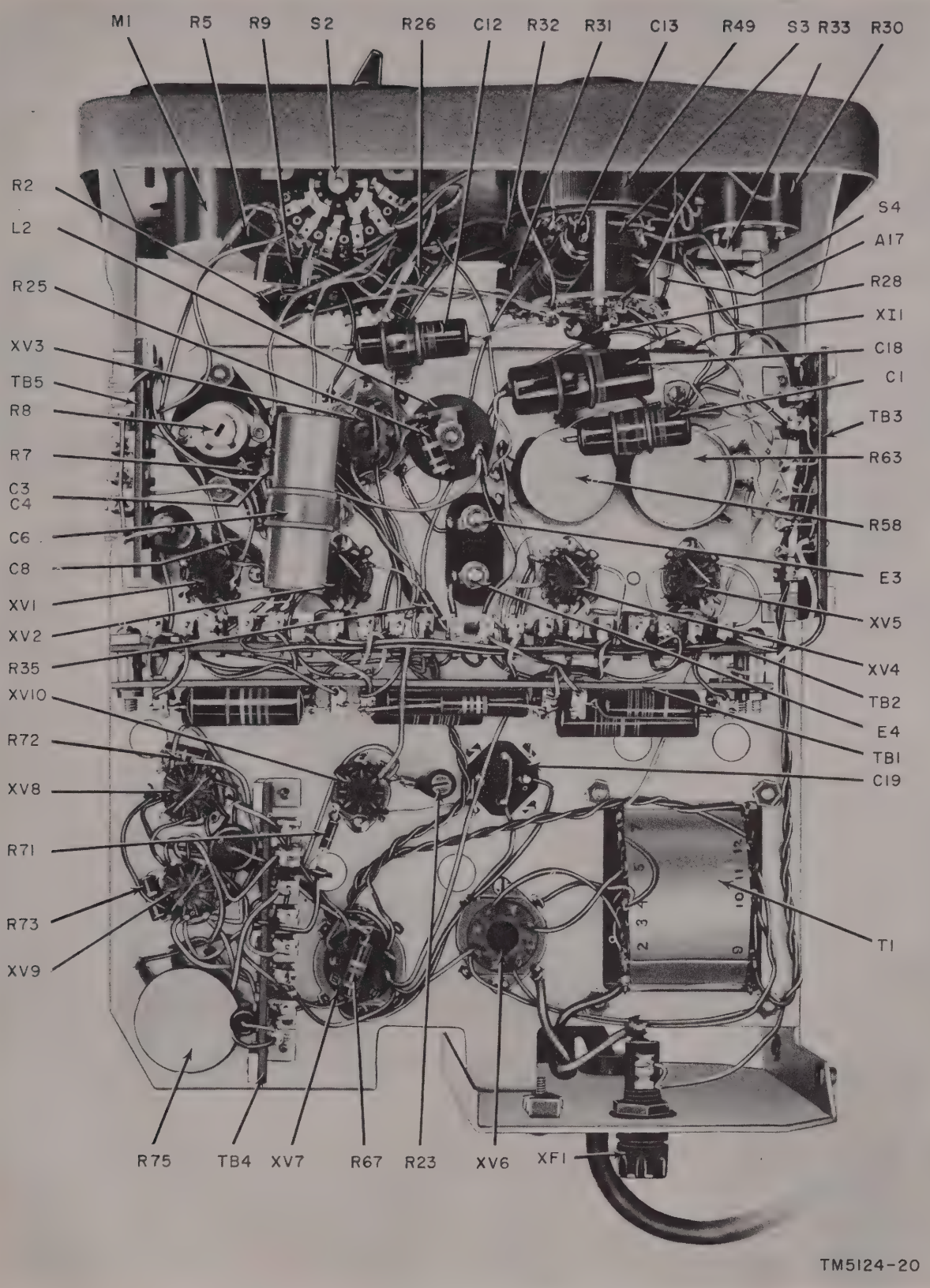
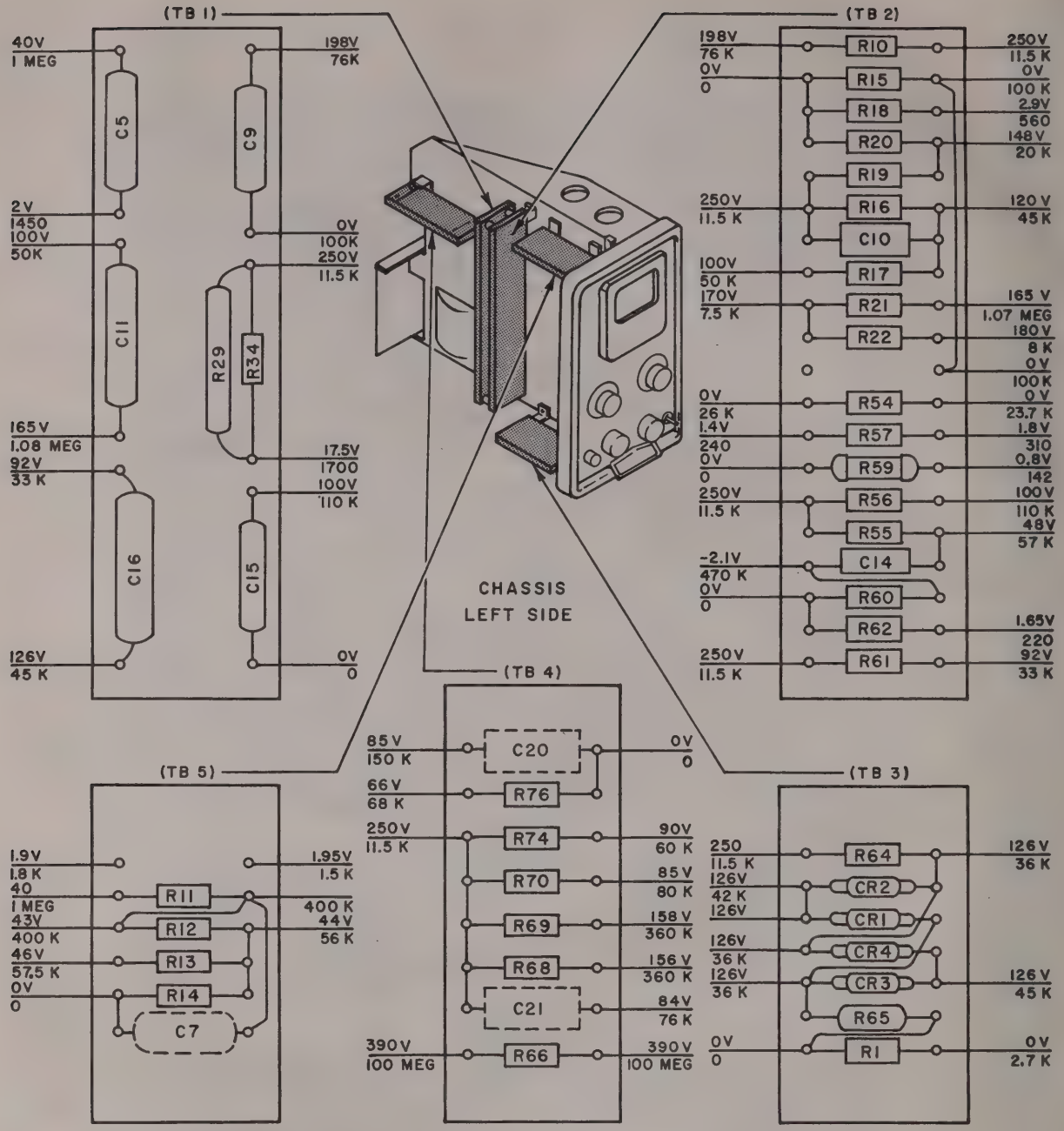


Figure 20. Summation bridge, left-hand side view of chassis.



NOTES:

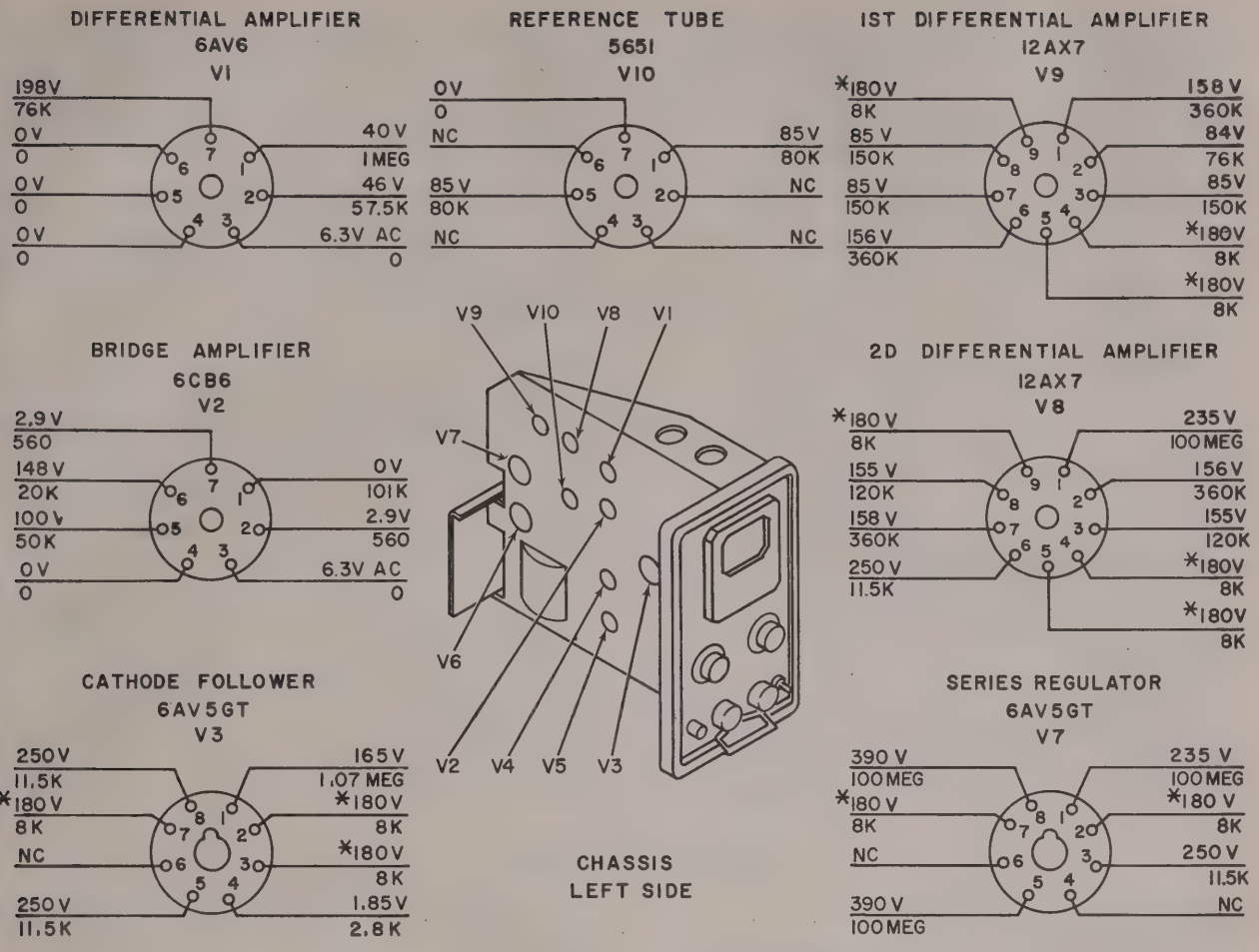
1. ALL VOLTAGES AND RESISTANCES MEASURED TO GROUND USING A 20,000 OHMS PER VOLT METER. RESISTANCES IN OHMS. ALL VOLTAGES DC UNLESS OTHERWISE SPECIFIED. K=1,000 MEG=1,000,000

2. PANEL CONTROLS SET AS FOLLOWS:
   - BIAS CURRENT TO 6-10MA (S5, TERMINAL NO. 5)
   - POWER RANGE TO 1.0MW
   - COEF. TO NEG.
   - RES. TO 200
   - ZERO SET
     - COARSE TO FULL CLOCKWISE
     - FINE TO FULL CLOCKWISE

3. WAVEGUIDE PROBE (THERMISTOR TYPE-200 OHM) CONNECTED TO INPUT CONNECTOR J1.

TM5124-21

Figure 21. Terminal board voltage and resistance diagram.



NOTES:

1. ALL VOLTAGES AND RESISTANCES MEASURED TO GROUND USING A 20,000 OHMS PER VOLT METER. RESISTANCES IN OHMS. ALL VOLTAGES DC UNLESS OTHERWISE SPECIFIED. K=1,000 MEG=1,000,000
2. PANEL CONTROLS SET AS FOLLOWS:
   - BIAS CURRENT TO 6-10MA (S5, TERMINAL NO. 5)
   - POWER RANGE TO 1.0MW
   - COEF. TO NEG.
   - RES. TO 200
   - ZERO SET
     - COARSE TO FULL CLOCKWISE
     - FINE TO FULL CLOCKWISE
3. WAVE GUIDE PROBE (THERMISTOR TYPE-200 OHM) CONNECTED TO INPUT CONNECTOR J1.
4. * 6.3V AC BETWEEN PINS 5-9 AND 4-9 OF V8 AND V9, BETWEEN PINS 2-7 OF V3 AND V7, AND 3-7 OF V3.
   5V AC BETWEEN PINS 2-8 OF V6.

TM5124-22

Figure 22. Tube socket voltage and resistance diagram.

43. Dc Resistance of Transformers and Coils

The dc resistances of the transformers and coils in Summation Bridge TS–779/U are listed below. Readings are taken with power disconnected.

Transformer or coil	Terminals	Ohms
T1	1–2	8.96.
	3–4	126.5.
	4–5	125.6.
	6–7	Continuity.
	8–9	9.05.
	10–11	Continuity.
	12–13	Continuity.
L1	1–2	165.0.
L2	1–2	228.0.

44. Dc Bias Current Check

A test of control and range dc bias current and an approximation of its calibration may be obtained as follows:

a. Remove tube V1. Turn on the summation bridge and allow it to warm up for 15 minutes.

b. Connect a 100-ohm ±1% resistor from the center contact of input connector J1 to the shell.

c. Measure the voltage across the resistor with a vtvm. The voltage reading obtained multiplied by 10 is the equivalent dc milliamperes. This can be done for any position of the BIAS CURRENT switch.

d. Adjust the ZERO SET controls FINE (R30) and COARSE (R33) until the proper readings are obtained. For example, with the BIAS CURRENT switch positioned at its maximum setting, the obtained voltage reading should be 1.6 volts.

e. If the error in dc bias current is extreme, and the power supply is known to be operating properly, check resistor R34. The value of this resistor is very critical and must be selected from one listed in the notes on the schematic diagram by the trial and error method.

f. Replace the oscillator tube V4 and operate the equipment as described in the equipment performance checklist paragraph 32.

Note. Since the operator can adjust the dc bias to accommodate each waveguide probe individually, only a significant error in the bias circuit would handicap operation.

Section II. REPAIRS

45. Replacement of Parts

Note. Several parts used in the summation bridge have smaller tolerances than those used in most electronic equipments. Resistors R4 and R34 are precision parts. If these parts require replacement, use a part of the *exact* value of the part removed. If parts with slightly different values are used, the calibration of the summation bridge will be inaccurate. Refer to paragraph 44*e* when replacing R34.

a. For the most part, the components of Wattmeter AN/URM–98 are easily reached and replaced if found faulty. The transformer, reactors, and terminal boards are mounted securely to the chassis with hexagonal nuts and machine screws.

b. If any of the switch wafers require replacement, carefully mark the wires connected to the wafer with tags to avoid misconnection when the new switch is installed. Follow this practice whenever replacement requires the disconnection of numerous wires.

c. All knobs are secured by a setscrew. The knobs must be put on in the correct position so that they point in the right direction in relation to the controls they are turning. When removing a knob, make a note of the position of the pointer and shaft and replace the knob in the same position.

46. Disassembly and Reassembly of Waveguide Probe MX–2144/U

a. Disassembly. To disassemble Waveguide Probe MX–2144/U (fig. 23), follow the procedure in (1) through (7) below.

(1) The input connector (J101) is secured in plastic housing O 106 by O-ring, O 103. To remove connector J101 from the housing, grasp the housing firmly with one hand and the connector with the other hand and pull apart.

(2) If it is difficult to separate the connector and the housing, secure a type N female connector in a vise and screw connector J101 on it. Grasp the housing firmly and pull it away from the connector.

(3) When connector J101 is removed from the housing, it releases spring O 105.

(4) Unscrew knurled nut E102 from conductor housing O 101 and lift out washers E104 and E103, capacitor C102 and contact O 102.

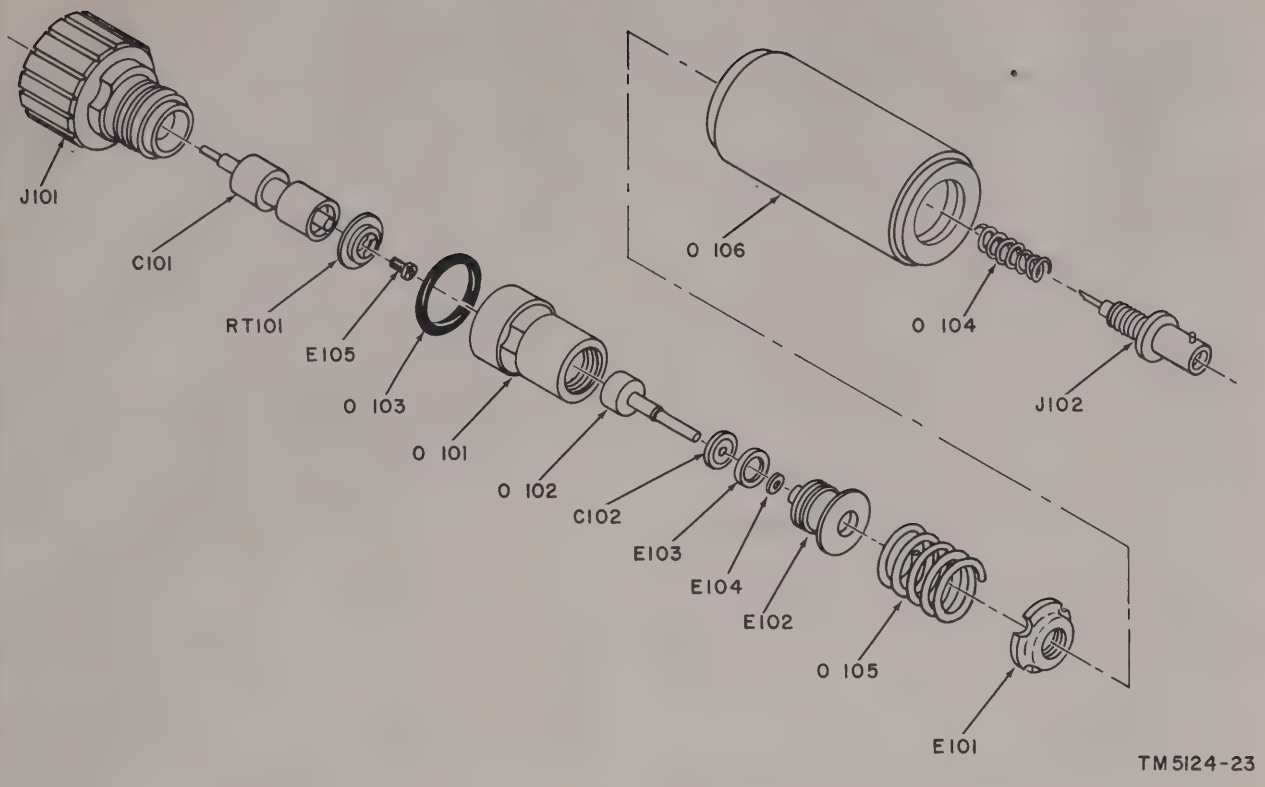


Figure 23. Waveguide Probe MX–2144/U.

(5) Hold connector J101 with a ⅝-inch open-end wrench. Use another ⅝-inch open-end wrench to unscrew conductor housing O 101.

(6) Unscrew E105 and remove thermistor assembly RT101 and capacitor C101.

(7) Hold housing O 106 firmly and unscrew connector J102. Use a pair of pliers gently to loosen the connector. This releases nut E101.

b. Reassembly. Reassemble the waveguide probe as follows:

(1) Place nut E101 in housing O 106. The nut has four detents in the head that fit into molded ridges inside the housing.

(2) Place spring O 104 over the contact end of connector J102. Insert the connector through the hole in the housing and screw it into nut E101. Tighten firmly, but be careful not to crack the plastic housing.

(3) Place thermistor assembly RT101 over the end of capacitor C101 and secure it with screw E105.

(4) Place capacitor C101 into the externally threaded end of connector J101. Screw conductor housing O 101 onto connector J101 and tighten securely.

(5) Place capacitor C102 over the end of contact O 102 and place the conductor, larger end first, into the conductor housing O 101.

(6) Place split washer E103 over the protruding end of contact O 102 followed by flat washer E104.

(7) Screw nut E102 into conductor housing O 101.

(8) Place spring O 105 in housing O 106. Press connector J101 into the housing until the O-ring snaps into the groove inside the housing.

47. Refinishing

Instructions for refinishing badly marred panels on exterior cabinets are given in TM 9–2851.

Section III. CALIBRATION AND ALINEMENT

48. Test Equipment Required for Calibration and Alinement

The following test equipment is required for calibration and alinement of Wattmeter AN/URM–98.

Item	Technical manual
Voltmeter Meter ME–30A/U.	Literature packed with equipment.
Variac CN–16/U	Literature packed with equipment.

49. Calibration and Alinement Procedures

To calibrate and aline the summation bridge properly, the procedures in *a* through *c* below should be followed in the sequence given. Power should be applied and the summation bridge allowed to warm up for 5 minutes before making these adjustments.

a. Regulated B+ Voltage. The regulated B+ voltage (+250 volts) contributes toward the stability of the summation bridge. Therefore, it is important that this voltage be set correctly before further adjustments are made. This adjustment is made in the following manner:

(1) Connect the vtvm between pin 3 of tube V7 and ground.
(2) Adjust resistor R75 until the vtvm reads 250 volts.
(3) Vary the ac power source using Variac CN–16/U. Check the adjustment in (2) above while varying the voltage from 105 to 125 volts ac or 210 to 250 volts ac. The 250-volt dc supply voltage should maintain itself throughout this line voltage range.

b. Voltmeter Circuit. To calibrate and aline the voltmeter circuit, proceed as follows:

(1) Connect the waveguide probe to input connector J1 on the summation bridge.
(2) Set the POWER RANGE switch to the 1.0 MW position.
(3) Connect vtvm to binding post E4 located on the right-hand side of the main chassis. This binding post is designated CAL. on the chassis.
(4) Adjust ZERO SET controls FINE (R30) and COARSE (R33) until the vtvm reads 0.465 volts. The meter (M1) on the summation bridge should read zero. If the meter does not read zero, adjust resistor R58. Resistor R58 is located on the right-hand side of the main chassis and is designated ZERO ADJ. (fig. 19).
(5) Adjust the ZERO SET controls FINE (R30) and COARSE (R33) until the vtvm reads 0.190 volts.
(6) Meter M1 on the summation bridge should now read full scale.
(7) If the meter does not read full scale, adjust resistor R63 until the meter pointer is at full scale deflection. R63 is located on the right-hand side of the main chassis and is designated F. S. ADJ. (fig. 19).
(8) After adjusting R63 repeat procedure in (1) through (6) above.

c. Bridge Circuit. It is extremely rare that the bridge circuit will ever require adjustment. It will be adjusted only if there is some doubt as to the accuracy of the results obtained in *b* above. Calibrate and aline the bridge circuits as follows:

(1) Turn the BIAS CURRENT switch to the OFF position.
(2) Connect the waveguide probe to input connector J1 on the summation bridge.
(3) Set the COEF and RES switches to the appropriate settings for the type of waveguide probe being used. (Set COEF switch on NEG position and RES switch on 200 position if Waveguide Probe MX–2144/U is used (par. 17).)
(4) Set POWER RANGE switch to the 1.0 MW position.
(5) Turn the ZERO SET controls FINE (R30) and COARSE (R33) to their full clockwise position.
(6) Connect the vtvm to the blank terminal lug on terminal board TB5 (fig. 20) with the violet wire attached.
(7) Adjust the BIAS CURRENT switch and ZERO SET controls FINE (R30) and COARSE (R33) until the vtvm reads 3 volts.
(8) Shift the vtvm test probe to the blank terminal lug on terminal board TB5 with the green wire attached. The multimeter should read 1 volt. If this reading is obtained, no adjustment is necessary.
(9) If the 1 volt reading was not obtained in

(8) above, set the BIAS CURRENT switch to the OFF position and the ZERO SET controls FINE (R30) and COARSE (R33) to their full clockwise position.

(10) Turn resistor R8 to the clockwise stop and back off ⅛-turn. Resistor R8 is located on the left-hand side of the main chassis (fig. 20).

(11) With the vtvm connected as in (6) above, advance the BIAS CURRENT switch until the vtvm approximately 2½ volts. Turn the ZERO SET controls FINE (R30) and COARSE (R33) counterclockwise until the vtvm reads exactly 3 volts.

(12) Connect the vtvm as in (8) above and note the error from 1 volt. Adjust resistor R8 to double the error in the same direction (i. e., if the error is ¼-volt low, adjust R8 so that the error is ½-volt low).

(13) Adjust the ZERO SET controls FINE (R30) and COARSE (R33) so that the vtvm reads exactly 1 volt.

(14) Shift the vtvm test probe to the violet lead ((6) above). Adjust ZERO SET controls FINE (R30) and COARSE (R33) until the vtvm reads 3 volts.

(15) Repeat the procedure in (12) through (14) above until no error is present.

CHAPTER 7

SHIPMENT AND LIMITED STORAGE AND DEMOLITION TO PREVENT ENEMY USE

Section I. SHIPMENT AND LIMITED STORAGE

50. Disassembly

To prepare Wattmeter AN/URM–98 for transportation and storage, disconnect the interconnect cable assembly and the waveguide probe. Roll up the power cord and tie with twine.

51. Repacking for Shipment or Limited Storage

Figure 3 illustrates one method of repacking the equipment. Specific directions for repacking Wattmeter AN/URM–98 are as follows:

a. Cushion the set on all surfaces with cells or pads fabricated of corrugated fiberboard. Place the cushioned wattmeter, together with technical manuals, within a close-fitting, slotted, corrugated box. Place the waveguide probe and interconnect cable assembly as shown in figure 3. Seal the entire closure with gummed tape and blunt all corners of the box.

b. Place the boxed wattmeter within a moisture-vaporproofed barrier, and heat-seal the closure. Place the moisture-vaporproofed wattmeter within a second close-fitting, slotted, corrugated fiberboard box and seal the entire closure with water-resistant tape or adhesive.

c. Overwrap the boxed equipment in waterproof barrier material. Completely seal all joints, seams, and closures with adhesive or other suitable seal equal in moisture resistance to that of the body material.

(1) Place the equipment, packaged as described above, within a nailed wooden box lined inside with a 2-inch thickness of excelsior compacted to 3 pounds per cubic foot. The shipping container should *not* be lined with a waterproof bag.

(2) For oversea shipment only, the shipping container should be strapped with metal straps as shown in figure 3.

Section II. DEMOLITION OF MATERIEL TO PREVENT ENEMY USE

52. General

The demolition procedures outlined in paragraph 53 will be used to prevent the enemy from using or salvaging this equipment. Demolition of the equipment will be accomplished only upon order of the commander.

53. Methods of Destruction

a. Smash. Smash the controls, tubes, coils, switches, capacitors, transformers, and meter; use sledges, axes, handaxes, pickaxes, hammers, crowbars, or heavy tools.

b. Cut. Cut the output and power cord and cable assemblies; use axes, handaxes, or machetes.

c. Burn. Burn cords and technical manuals; use gasoline, kerosene, oil, flamethrowers, or incendiary grenades.

d. Bend. Bend panel and cabinet.

e. Dispose. Bury or scatter the destroyed parts in slit trenches, foxholes, or throw them into streams.

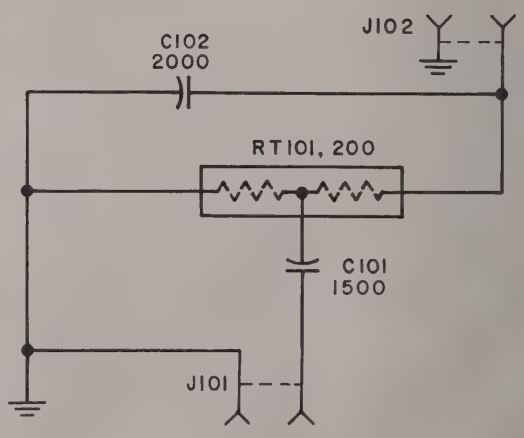
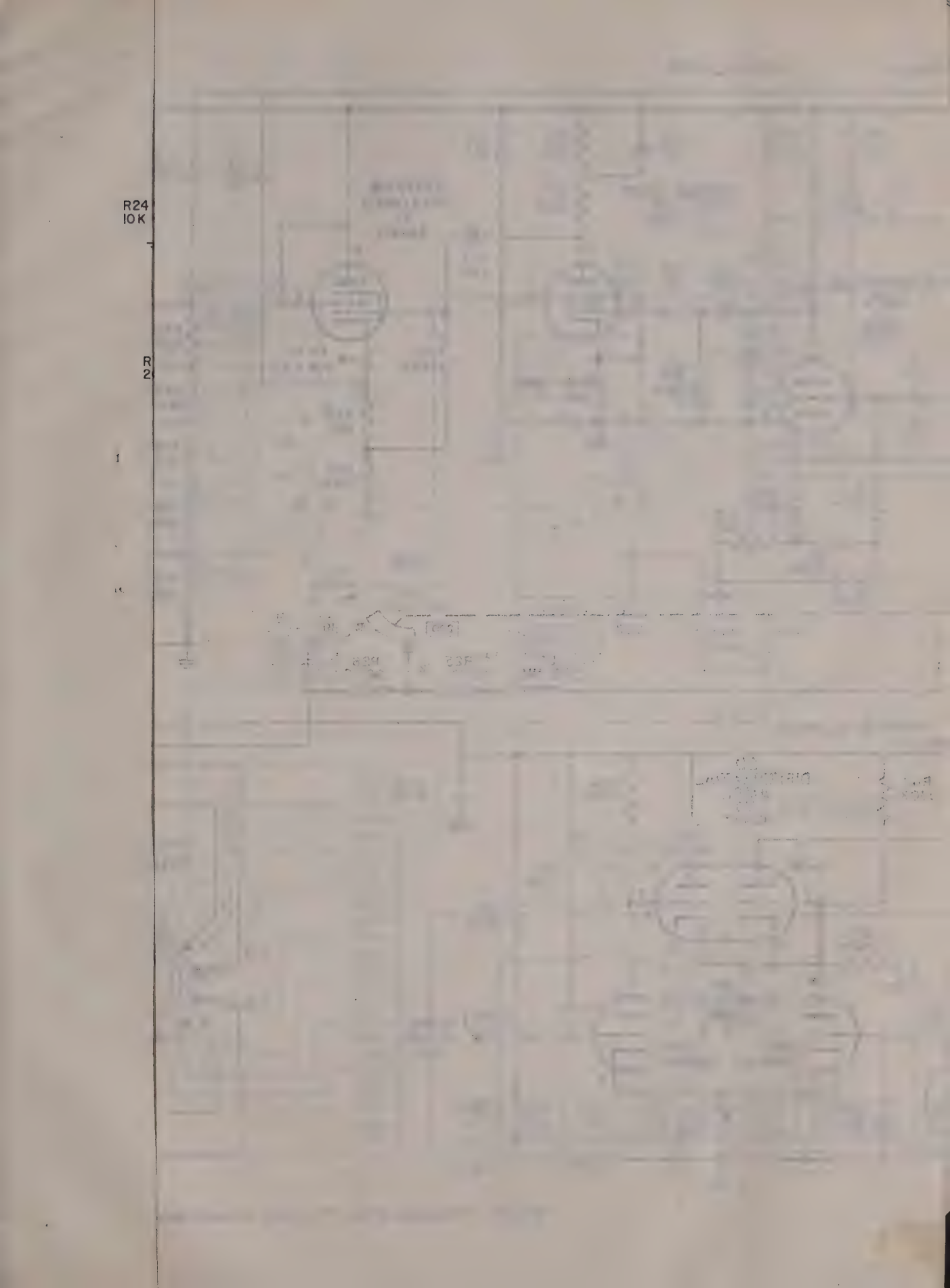


Figure 24. Waveguide Probe MX-2144/U, schematic diagram.


R24
10K

CHAPTER 7

SHIPMENT AND LIMITED STORAGE AND DEMOLITION TO PREVENT ENEMY USE

Section I. SHIPMENT AND LIMITED STORAGE

50. Disassembly

To prepare Wattmeter AN/URM–98 for transportation and storage, disconnect the interconnect cable assembly and the waveguide probe. Roll up the power cord and tie with twine.

51. Repacking for Shipment or Limited Storage

Figure 3 illustrates one method of repacking the equipment. Specific directions for repacking Wattmeter AN/URM–98 are as follows:

a. Cushion the set on all surfaces with cells or pads fabricated of corrugated fiberboard. Place the cushioned wattmeter, together with technical manuals, within a close-fitting, slotted, corrugated box. Place the waveguide probe and interconnect cable assembly as shown in figure 3. Seal the entire closure with gummed tape and blunt all corners of the box.

b. Place the boxed wattmeter within a moisture-vaporproofed barrier, and heat-seal the closure. Place the moisture-vaporproofed wattmeter within a second close-fitting, slotted, corrugated fiberboard box and seal the entire closure with water-resistant tape or adhesive.

c. Overwrap the boxed equipment in waterproof barrier material. Completely seal all joints, seams, and closures with adhesive or other suitable seal equal in moisture resistance to that of the body material.

(1) Place the equipment, packaged as described above, within a nailed wooden box lined inside with a 2-inch thickness of excelsior compacted to 3 pounds per cubic foot. The shipping container should *not* be lined with a waterproof bag.

(2) For oversea shipment only, the shipping container should be strapped with metal straps as shown in figure 3.

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The demolition procedures outlined in paragraph 53 will be used to prevent the enemy from using or salvaging this equipment. Demolition of the equipment will be accomplished only upon order of the commander.

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a. Smash. Smash the controls, tubes, coils, switches, capacitors, transformers, and meter; use sledges, axes, handaxes, pickaxes, hammers, crowbars, or heavy tools.

b. Cut. Cut the output and power cord and cable assemblies; use axes, handaxes, or machetes.

c. Burn. Burn cords and technical manuals; use gasoline, kerosene, oil, flamethrowers, or incendiary grenades.

d. Bend. Bend panel and cabinet.

e. Dispose. Bury or scatter the destroyed parts in slit trenches, foxholes, or throw them into streams.

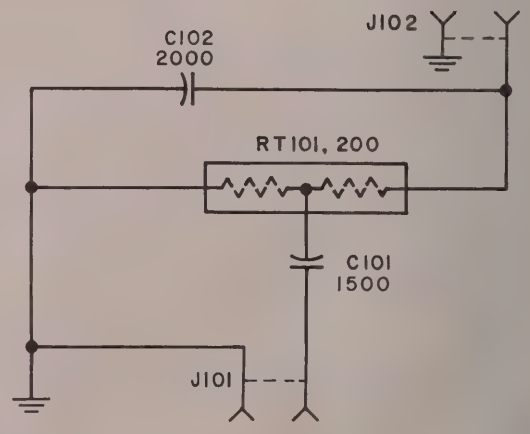
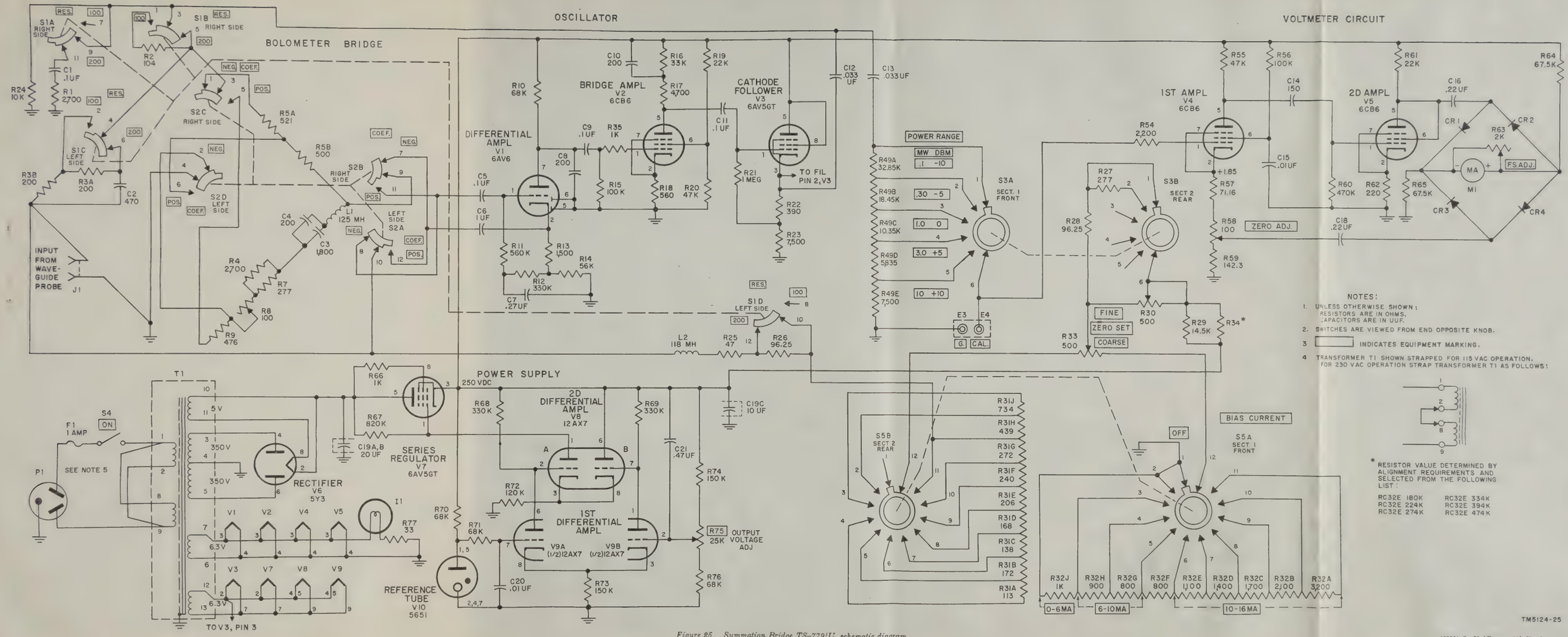


Figure 24. Waveguide Probe MX–2144/U, schematic diagram.



NOTES:

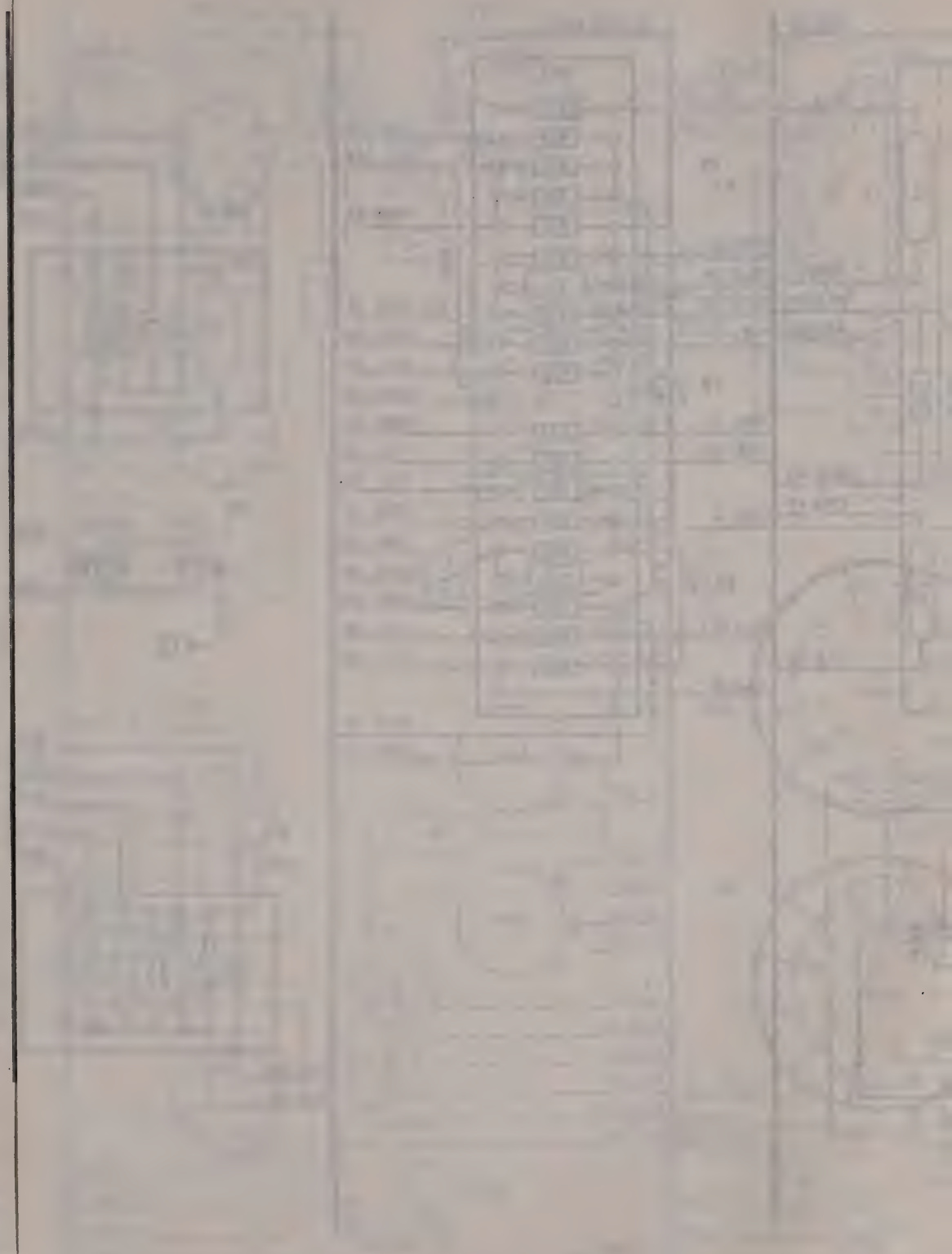
1. UNLESS OTHERWISE SHOWN; RESISTORS ARE IN OHMS, CAPACITORS ARE IN UUF.
2. SWITCHES ARE VIEWED FROM END OPPOSITE KNOB.
3. ▭ INDICATES EQUIPMENT MARKING.
4. TRANSFORMER T1 SHOWN STRAPPED FOR 115 VAC OPERATION. FOR 230 VAC OPERATION STRAP TRANSFORMER T1 AS FOLLOWS:

* RESISTOR VALUE DETERMINED BY ALIGNMENT REQUIREMENTS AND SELECTED FROM THE FOLLOWING LIST:

RC32E 180K	RC32E 336K
RC32E 224K	RC32E 394K
RC32E 274K	RC32E 474K

TM5124-25

Figure 25. Summation Bridge TS-779/U, schematic diagram.



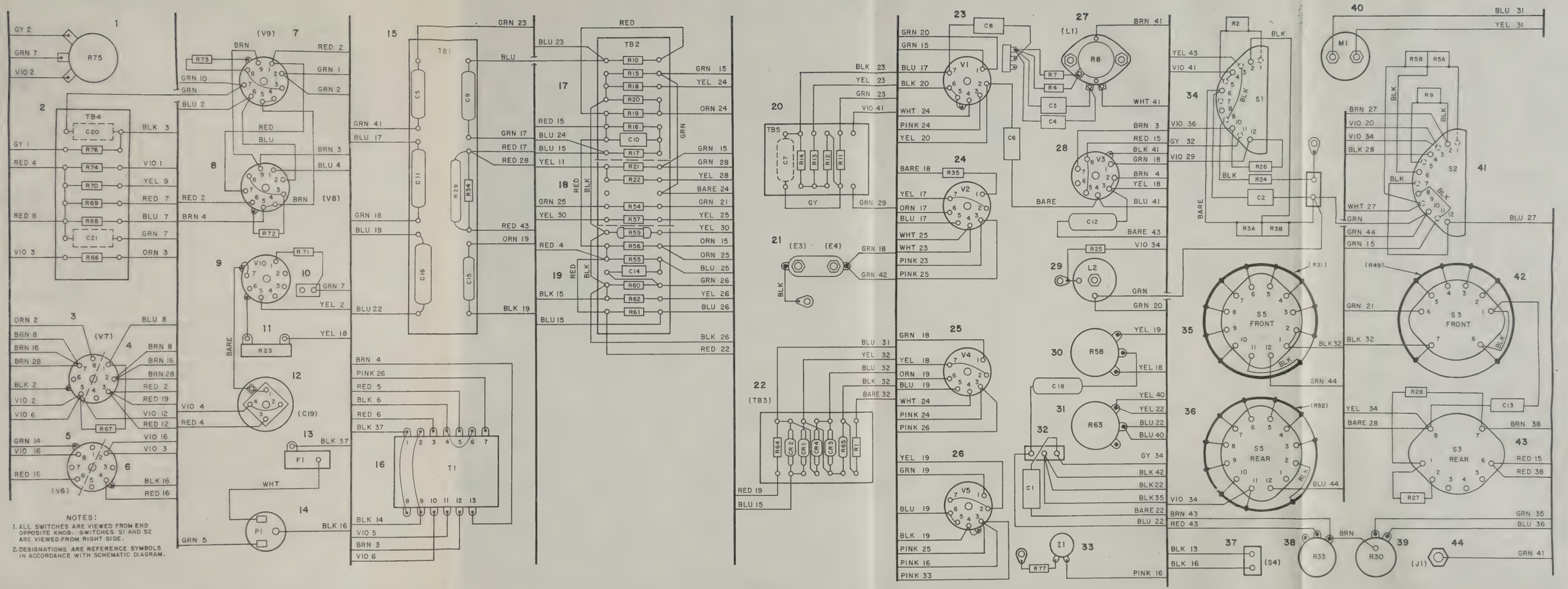
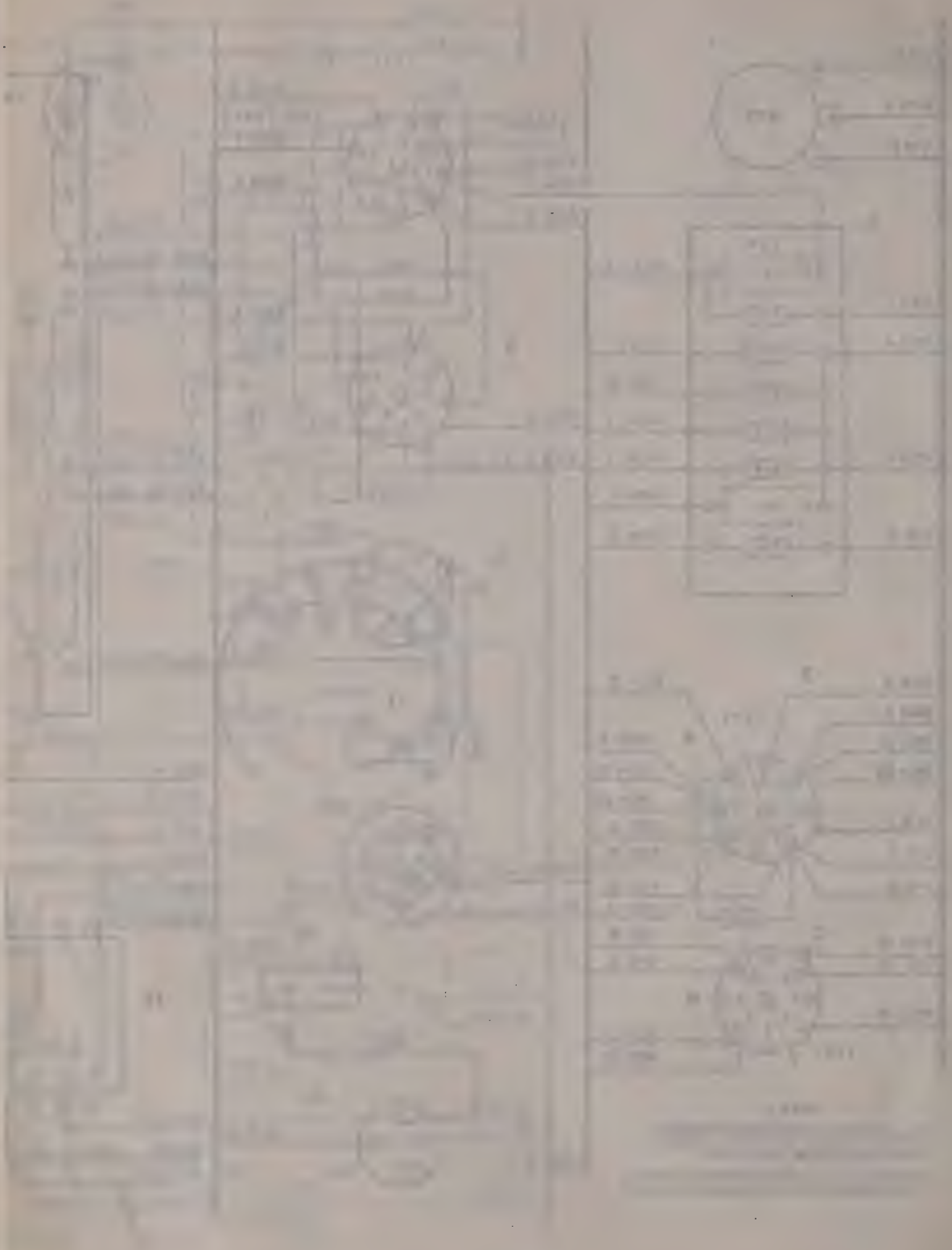
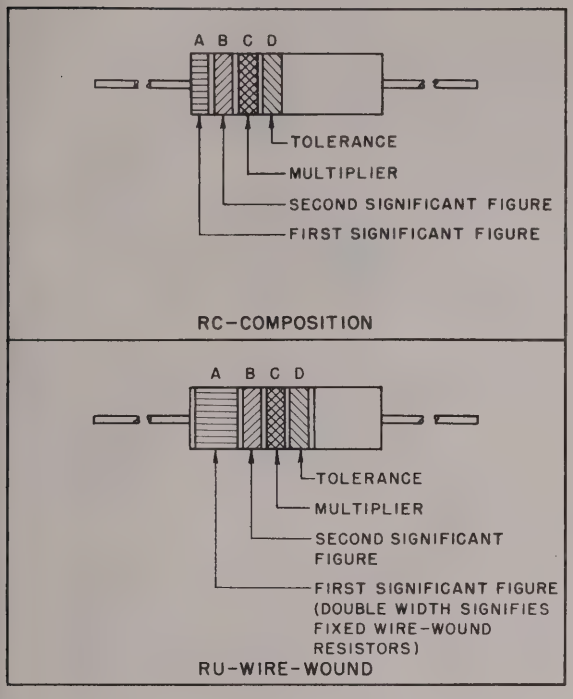

NOTES:
1. ALL SWITCHES ARE VIEWED FROM END OPPOSITE KNOB. SWITCHES S1 AND S2 ARE VIEWED FROM RIGHT SIDE.
2. DESIGNATIONS ARE REFERENCE SYMBOLS IN ACCORDANCE WITH SCHEMATIC DIAGRAM.
TM 5124-26
409231 O -56 (Face p. 44) No. 2

Figure 26. Summation Bridge TS-779/U, wiring diagram.

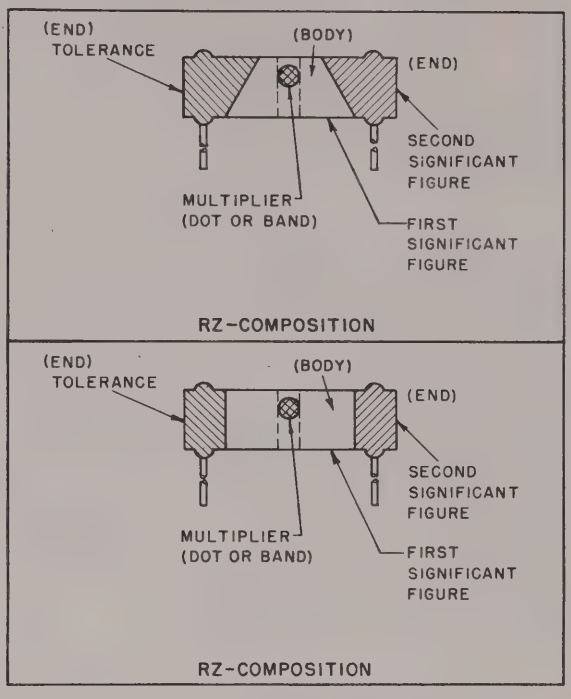


RESISTOR COLOR CODE MARKING
(MIL-STD RESISTORS)

AXIAL-LEAD RESISTORS (INSULATED)



RADIAL-LEAD RESISTORS (UNINSULATED)



RESISTOR COLOR CODE

BAND A OR BODY*		BAND B OR END*		BAND C OR DOT OR BAND*		BAND D OR END*	
COLOR	FIRST SIGNIFICANT FIGURE	COLOR	SECOND SIGNIFICANT FIGURE	COLOR	MULTIPLIER	COLOR	RESISTANCE TOLERANCE (PERCENT)
BLACK	0	BLACK	0	BLACK	1	BODY	± 20
BROWN	1	BROWN	1	BROWN	10	SILVER	± 10
RED	2	RED	2	RED	100	GOLD	± 5
ORANGE	3	ORANGE	3	ORANGE	1,000		
YELLOW	4	YELLOW	4	YELLOW	10,000		
GREEN	5	GREEN	5	GREEN	100,000		
BLUE	6	BLUE	6	BLUE	1,000,000		
PURPLE (VIOLET)	7	PURPLE (VIOLET)	7				
GRAY	8	GRAY	8	GOLD	0.1		
WHITE	9	WHITE	9	SILVER	0.01		

*FOR WIRE-WOUND-TYPE RESISTORS, BAND A SHALL BE DOUBLE-WIDTH. WHEN BODY COLOR IS THE SAME AS THE DOT (OR BAND) OR END COLOR, THE COLORS ARE DIFFERENTIATED BY SHADE, GLOSS, OR OTHER MEANS.

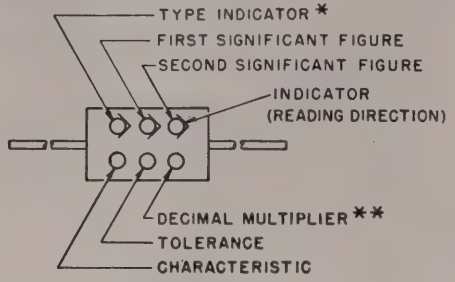
EXAMPLES (BAND MARKING):
10 OHMS ±20 PERCENT: BROWN BAND A; BLACK BAND B; BLACK BAND C; NO BAND D.
4.7 OHMS ±5 PERCENT: YELLOW BAND A; PURPLE BAND B; GOLD BAND C; GOLD BAND D.

EXAMPLES (BODY MARKING):
10 OHMS ±20 PERCENT: BROWN BODY; BLACK END; BLACK DOT OR BAND; BODY COLOR ON TOLERANCE END.
3,000 OHMS ±10 PERCENT: ORANGE BODY; BLACK END; RED DOT OR BAND; SILVER END.

STD-RI

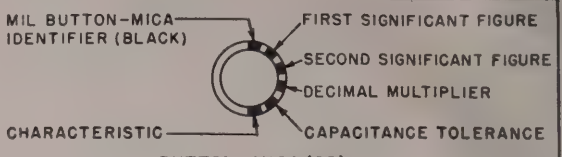
Figure 27. MIL-STD resistor color codes.

CAPACITOR COLOR CODE MARKING
(MIL-STD CAPACITORS)

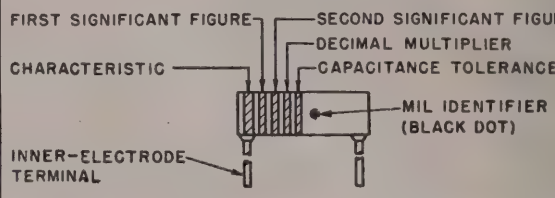


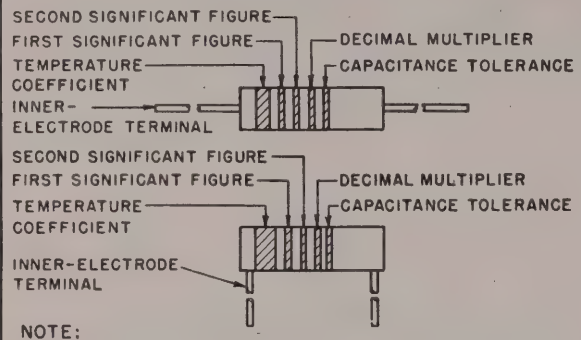
* BLACK DOT: MICA DIELECTRIC
SILVER DOT: PAPER DIELECTRIC
** INDICATES NUMBER OF ZEROS ON PAPER TYPE.

MICA (CM) AND PAPER (CN)



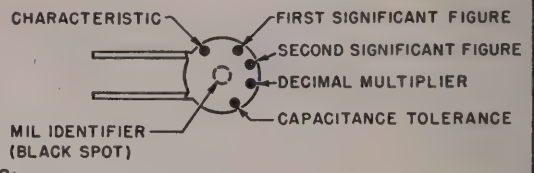
BUTTON-MICA (CB)





NOTE:
SPOTS MAY BE USED INSTEAD OF BANDS; TEMPERATURE COEFFICIENT MARKING IS LARGER.

CERAMIC-TEMPERATURE COMPENSATING (CC)



NOTES:
1. SPOTS MAY BE USED ON TUBULAR CAPACITORS; CHARACTERISTIC SPOT IS LARGER AND MIL IDENTIFIER IS ON SIDE DIAMETRICALLY OPPOSITE COLOR SPOTS.
2. MIL IDENTIFIER OF DISK TYPE IS ON REVERSE SIDE; CHARACTERISTIC SPOT IS LARGER OR SPACE BETWEEN CHARACTERISTIC AND TOLERANCE SPOTS IS THREE TIMES SPACE BETWEEN ADJACENT SPOTS.
3. TOLERANCE: YELLOW, +100%, -20%.

CERAMIC-GENERAL PURPOSE (CK)

CAPACITOR COLOR CODE

COLOR	SIG FIG.	MULTIPLIER		CHARACTERISTIC[1]				TOLERANCE [2]					TEMPERATURE COEFFICIENT (UUF/UF/°C)
		DECIMAL	NUMBER OF ZEROS	CM	CN	CB	CK	CM	CN	CB	CC		
											OVER 10UUF	10UUF OR LESS	CC
BLACK	0	1	NONE		A			20	20	20	20	2	ZERO
BROWN	1	10	1	B	E	B	W				1		-30
RED	2	100	2	C	H		X	2		2	2		-80
ORANGE	3	1,000	3	D	J	D			30				-150
YELLOW	4	10,000	4	E	P								-220
GREEN	5		5	F	R						5	0.5	-330
BLUE	6		6		S								-470
PURPLE (VIOLET)	7		7		T	W							-750
GRAY	8		8			X						0.25	+30
WHITE	9		9								10	1	-330(±500) [3]
GOLD		0.1						5		5			+100
SILVER		0.01						10	10	10			

1. LETTERS ARE IN TYPE DESIGNATIONS GIVEN IN MIL-C SPECIFICATIONS.
2. IN PERCENT, EXCEPT IN UUF FOR CC-TYPE CAPACITORS OF 10 UUF OR LESS.
3. INTENDED FOR USE IN CIRCUITS NOT REQUIRING COMPENSATION.

STD-CI

Figure 28. MIL-STD capacitor color codes.

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[AG 413.44 (14 Nov 56)]

By Order of *Wilber M. Brucker*, Secretary of the Army:

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Chief of Staff.

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For explanation of abbreviations used see, SR 320–50–1.

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